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# CALCIFICATION OF THE TENDON CUFF OF THE SHOULDER

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CODMAN and others have demonstrated that the condition called subdeltoid bursitis, or periarthritis, is in reality a lesion of the tendon cuff of the shoulder. It may be a calcification, a tear, or a "tendonitis." Calcification of the tendon cuff is probably the most common cause of pain and disability at this joint. Codman deserves great credit for his contributions to our knowledge of these shoulder lesions, especially his demonstration of the relationships between bursa and tendons, and between the clinical and pathological features, and the operative treatment. He has shown that the primary lesion is in the tendon, and that the bursitis is secondary. The present discussion is limited to calcified tendons.

Javjavay, in 1867, and Gruber, in 1869, described the pathology of "subdeltoid bursitis." Duplay (12–15), in 1872 and 1896, without benefit of roentgenography, described "periarthritis" of the shoulder, probably including in this vague term cases of calcification. Kuester, in 1902, reported additional cases. Harrington and Codman (7) did the first operation upon a shoulder with calcification in the tendon cuff in 1902, but did not recognize its true nature and considered it an abscess. Painter and Codman (7) operated upon a second patient in 1905, and then recognized the true nature of the lesion, and the relation between the clinical and the pathologic picture. Baer in 1907, and Bergemann and Stieda, in 1908, also advised operation for this condition, and the latter further described the pathology. Moschowitz in 1915, and Codman and Akerson (11) in 1931, described the pathology of their cases. Numerous authors have reported cases and the results of treatment by physical and roentgen therapy. Aspiration of the bursa was reported by Flint, in 1913, multiple puncture of the calcified area of the tendon by Milgrim.

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## ANATOMY

The tendons of the subscapularis, supraspinatus, infraspinatus, and teres minor muscles converge and fuse with the capsule of the shoulder joint about 1 inch from its distal margin. The common tendon-capsule cuff thus formed is attached to the superior margin of the tuberosities and the anatomic neck of the humerus. The subdeltoid or subacromial bursa lies upon this tendon cuff and the greater tuberosity, and is covered by the deltoid muscle, acromion process, and coracoacromial ligament. It is a thin walled, transparent, hemispherical pouch, averaging about 1½ inches in diameter, and lined with synovial membrane. The floor of the bursa is attached to, and moves with, the cuff and great-

er tuberosity, and the roof moves with the structures covering it, by means of the redundant folds at its margin. The tendon cuff is normally seen shining through the superior half of the bursal floor. The intertubercular groove and biceps tendon are seen and felt near its medial portion.

### PATHOLOGY

The bursa and the calcareous deposit were exposed at operation in 23 shoulders. The bursal wall was usually thickened and opaque, edematous and vascular. Only one bursa contained calcareous material, in a thin suspension. Small villi were present opposite the tendon lesion in several cases. The membrane in the more chronic lesions was firmer and white.

The calcareous deposit could be identified in the floor of the bursa as a white or yellowish area, often a raised mound resembling a "boil," surrounded by a reddish zone. The white area was softer and more elastic than normal tendon, but sometimes quite tense. Upon incision the contents might be a milk-like liquid and spurt forth under pressure; creamy or cheese-like and ooze forth like tooth paste from a tube; or dry and amorphous, granular or sand-like, having to be dug out with knife point or curette. The number of cavities varied from one to five, their lengths from ¼ to 1½ inches, their contents from 0.5 to 4 cubic centimeters. When there were two or more cavities, the contents might vary in the different cavities. Usually the cavities were separate and distinct, but some of them communicated or had peripheral burrows. Some of the cavities were smooth walled but not encapsulated; others were irregular and vaguely outlined. The cavities lay in tendon, the fibers of which were softened, stringy, and dull. The degenerated tendon often was infiltrated with calcareous granules or clumps. Bare bone was exposed in the base of some of the cavities. No communication with the joint was demonstrated, and only one had ruptured into the bursa. No frank tear of the tendon was seen. Most of the deposits were in the tendon of the supraspinatus, but there were several in the infraspinatus and the teres minor, one in the subscapularis muscle.

Microscopic sections from the tendons demonstrated degenerated and frayed ligamentous, fibrous, and fibrocartilaginous connective tissue. The degenerated areas contained calcium salt deposits in the form of conglomerate and scattered fine and coarse granules and scattered amorphous nodules, the deposits being most extensive in the areas of greatest degeneration. Foreign body giant cells were sometimes present. Evidence of repair was often manifested by the picture of connective tissue proliferation and an associated abundance of blood capillaries. The synovial membrane of the adjacent bursa was edematous, hyperemic, thickened and exhibited hyperplasia of synovial cells, sometimes with villous formation.

### ETIOLOGY

The cause of the calcification was not obvious, but it appeared that there had been first a degeneration of the tendon followed by the deposition of calcium salts. The degeneration may be the result of impaired circulation, attrition, or both. The supraspinatus tendon, with the arm at the side, makes a curve of about 40 degrees around the head of the humerus to its insertion. This is the common working position of the arm, and the abduction of the arm in this position, especially with sudden or resisted movements, causes considerable pressure against the tendon. Any irregularity beneath the tendon increases this pressure and wear. There is a similar situation, for example, where the short extensor and abductor of the thumb cross the radial styloid, producing a tenosynovitis (de Quervain's disease). Motion picture film may be badly scratched in a similar way when it is wound jerkily on a reel. Similar effects may be produced in the tendons of the shoulder rotators by similar rotary motions. Constantly repeated motions seem more likely to produce this effect than varied and intermittent ones. The occupational history of the patients in this series, and the manner in which they have used their arms, tends to confirm this theory of the mechanism of the cause of this condition. Thus the use of the arm at the side, with sudden, jerky, or resisted motions toward abduction or rotation, constantly repeated, ap-

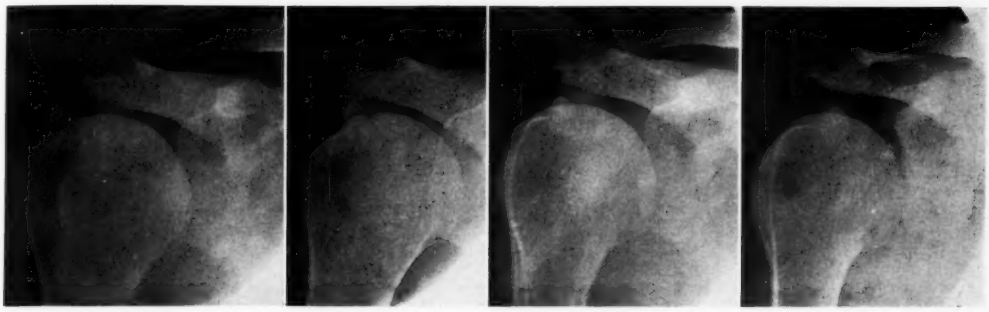

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Fig. 1. Roentgenograms showing moderate calcareous deposits in supraspinatus tendon, plainly visible in all views. Pain which was present for 2 days improved spontaneously. a, Anteroposterior view; b, internal rotation 45 degrees; c, external rotation 45 degrees; d, external rotation 90 degrees.

pears to be the cause of degeneration and calcification of the tendons of the shoulder cuff.

### COURSE AND STAGES

The symptoms and signs of this disease are not proportional to the size, shape, number, and location of the calcareous deposits, nor even to their type. Large deposits may be almost symptomless; small deposits may be associated with considerable pain. Similar symptoms and signs may be present in the absence of deposits. Mild symptoms may suddenly become severe or severe symptoms subside with no change in the roentgenogram. It is probable that the most important factor in relation to the severity of symptoms and signs is the tension of the calcareous material in the substance of the tendon.

The calcareous deposits often increase, occasionally decrease in size and density over a period of months or years, but may change in a few days. Rupture of the deposit into the bursa results in a change in the location and density of the calcareous material and is usually followed by immediate relief of symptoms and absorption of the material. Occasionally the deposits in the tendons are absorbed, but most of them persist for many years unless there is a spontaneous or surgical opening.

The disease may be described as being in an acute, chronic, or quiescent stage, but there is little relationship between the stage of the disease so expressed and its duration, as one of long duration may suddenly become acute, while one of short duration may be, and remain, clinically quiescent.

Thus it is seen that there is usually little correlation between the clinical and roentgenographic features of the disease.

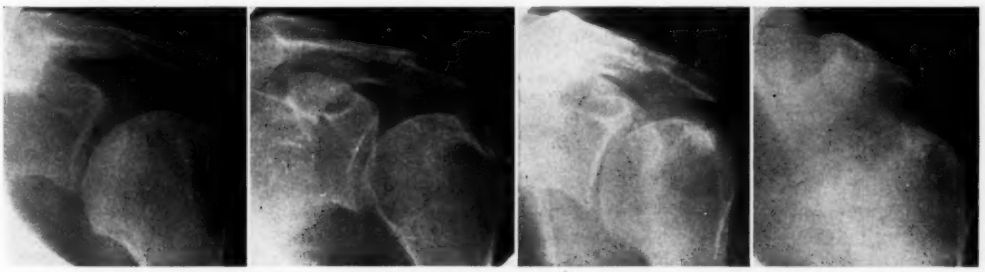

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Fig. 2. Roentgenograms revealing large, multiple calcareous deposits in supraspinatus tendon, showing well in anteroposterior and internal rotation views, partly hidden by greater tuberosity in external rotation views. Pain which was present for 1 week was relieved in 4 weeks with roentgen therapy. a, Anteroposterior view; b, internal rotation 45 degrees; c, external rotation 45 degrees; d, external rotation 90 degrees.

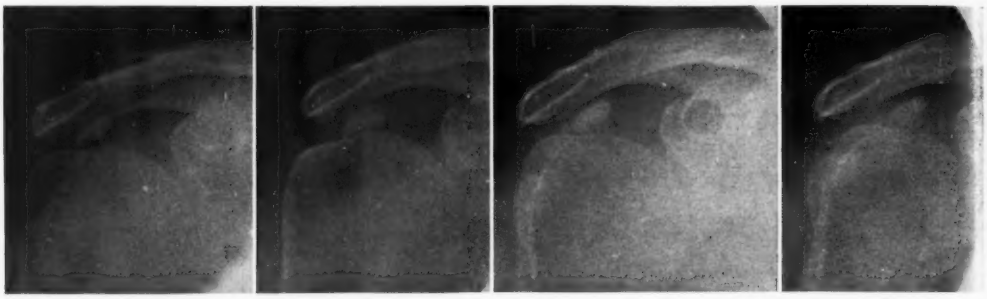

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Fig. 3. Roentgenograms revealing moderate calcareous deposits in supraspinatus tendon, plainly visible in all views. Pain which was present for 2 months became worse with diathermy. a, Anteroposterior view; b, internal rotation 45 degrees; c, external rotation 45 degrees; d, external rotation 90 degrees.

### THE CASES

One hundred consecutive cases have been included in this series. The average age was 43 years, the range from 24 to 63. Only 1 patient was under 30 years, 12 past 50 years. Forty per cent were men, 60 per cent women. The right shoulder was affected in 62 per cent, the left in 38 per cent, 14 per cent being bilateral. Definite injury was mentioned in only 3 cases. Housekeeping was the most common occupation, while stenography, filing, and similar activities requiring repeated sudden movements of the shoulders, were done by most of the other patients. There was no evidence that focal or other infection had any relation to the disease.

### SYMPTOMS AND SIGNS

The symptoms were pain, limitation of motion, and disability. They varied in severity from slight to severe. The duration of symptoms was 2 days to 20 years, averaging 2 years. Only 24 had symptoms of less than 1 month's duration; nearly all of the others came in because of exacerbations.

The pain was usually described as an ache in the anterior shoulder region, often radiating down the anterior border of the deltoid to its insertion. The pain overflowed into the forearm and upper shoulder girdle region in the more severe cases. It was worse at night, making it difficult to find a comfortable position in bed, especially on the affected side. The pain was worse on activity, and often affected by weather. Abduction, or putting the hand behind the head, was difficult or impossible. Disability varied in proportion to the amount of pain, and the use to which the arm was put.

The arm was usually held at the side in internal rotation. There was atrophy of the deltoid and spinatus muscles. Tenderness of various degrees was found, usually anterolaterally just above the greater tuberosity because of the more frequent involvement of the supraspinatus muscle. The tenderness was lateral to the tuberosity with involvement of

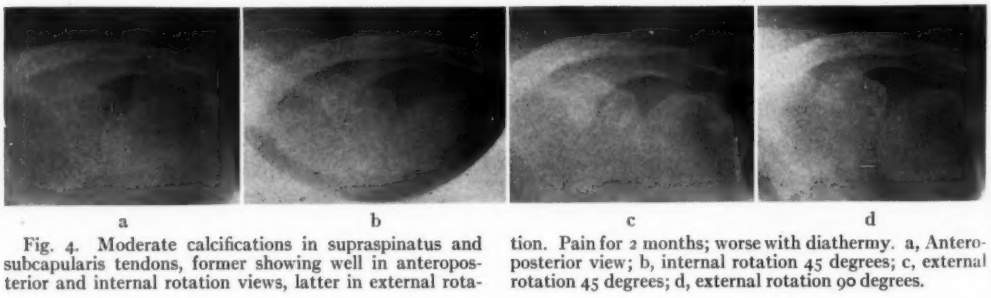

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Fig. 4. Moderate calcifications in supraspinatus and subcapularis tendons, former showing well in anteroposterior and internal rotation views, latter in external rotation. Pain for 2 months; worse with diathermy. a, Anteroposterior view; b, internal rotation 45 degrees; c, external rotation 45 degrees; d, external rotation 90 degrees.

a b c d

Fig. 5. Large, multiple calcareous deposits in supraspinatus tendon, showing well in anteroposterior and internal rotation views, displaced medially in external rotation views. Pain of 2 years' duration. a, Anteroposterior view; b, internal rotation 45 degrees; c, external rotation 45 degrees; d, external rotation 90 degrees.

the infraspinatus, posteriorly for the teres minor and anteromedially for the subscapularis. Abduction was usually painful, especially at the point where the bursa slides under the acromion. Painful rotation, particularly externally, was indicative of inflammation of the bursa. *Resisted motions* were painful, external rotation for involvement of the infraspinatus and teres minor, internal rotation for the subscapularis, abduction for the supraspinatus. Active or resisted motion was more painful than passive motion because of the increased tension on the diseased area and the increased pressure of the deltoid muscle.

Tears of the tendons of the shoulder cuff are distinguished by their sudden onset with injury, swelling at the tuberosity, a tender depression above the tuberosity, inability to abduct the arm, and difficulty in maintaining it in abduction whereas rotation is only slightly affected. There is the disturbance of "scapulohumeral rhythm," and the "jog, wince and crepitus" described by Codman, as the torn edge passes under and out from the acromion.

Tendonitis ("frozen shoulder") is characterized by considerable limitation of all motion, with pain and spasm, and diffuse tenderness. The tendon of the long head of the biceps may be adherent to the groove in such shoulders.

### LABORATORY

Routine urine examinations, blood counts, and erythrocyte sedimentation rates were normal in all cases, and cultures of the contents of the cavities resulted in no growths.

### ROENTGENOGRAMS

The typical roentgenogram revealed an amorphous calcification in the angle between the humeral head, greater tuberosity, and acromion. However, there was considerable variation in the number, size, shape, density, homogeneity, continuity, and location of the calcifications. Usually there was one main mass, once as many as five. The mass generally was roughly elliptical, measuring from 1½ by ¾ to ⅜ by 3/16 inches. It might be continuous or broken, of even or variable density, rounded or angular, sharp and smooth edged or irregular and fading. The smooth edged mass of even density, but faintly flocculent under magnification of two or three diameters, was usually liquid, whereas the broken ones of uneven density proved to be infiltrating and gritty. The supraspinatus calcifications were located just above the junction of the greater tuberosity and head, whereas those of the infraspinatus and teres minor were lower and superimposed upon the tuberosity except in internal rotation; that of the subscapularis was superimposed on the joint in internal rotation, on the head in external rotation.

The bursal calcium shadow extends down over the tuberosity, and is apt to be faint and homogeneous.

The roentgenogram should be made tangential to the acromiohumeral interval, and

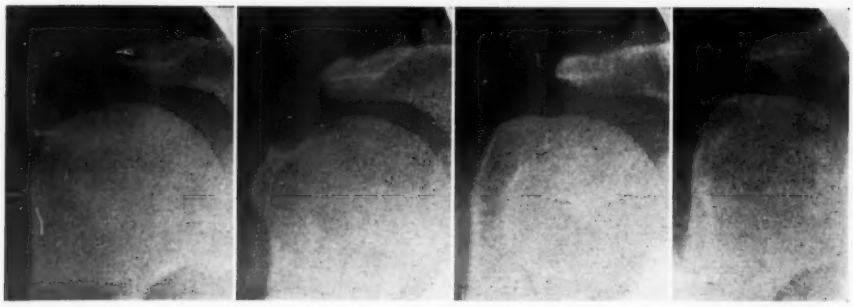

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Fig. 6. Roentgenograms showing moderate calcifications in infraspinatus tendons, visible only in internal rotation. Pain for 5 months; improved spontaneously over 8 months' period. a, Anteroposterior view; b, internal rotation 45 degrees; c, external rotation 45 degrees; d, external rotation 90 degrees.

*views should be made in 45 degrees, internal, and 45 and 90 degrees' external rotation as well as in the neutral position.* The single view, even stereoscopic, may fail to show one or more of the calcifications. Fluoroscopy may be of considerable aid in locating the deposits.

### TREATMENT

Analysis of the effect of treatment in the hundred cases reveals:

Pain and spasm may be relieved in some cases, especially the acute ones of short duration, by any one of several treatments. Rupture of the calcareous deposit into the bursa, spontaneously or by any form of treatment, gives immediate relief. Rest alone may give some comfort. Additional relief may be obtained by immobilization or suspension in a comfortable position. However, immobilization tends to produce stiffness and should be used only for a short time if at all, and then combined with exercises as below. Immobilization is usually accomplished with the arm at the side in internal rotation, causing contracture resulting in limited abduction and external rotation. This tendency is aggravated by the facts that the arm normally rests at the side and that external rotation is the least common motion, and is normally less than internal rotation.

Heat, in the form of a lamp, hot water bag, electric pad, or hot packs, may provide some relief. Short or long wave diathermy may relieve some shoulders, and may even be followed by absorption of the calcareous material in the early acute ones. However, an acute shoulder, with inflammation of the bursa, or tension in the tendon, is often made worse by heat.

Cold is usually more comforting than heat, especially in the very acute cases. Ice packs may be used, but the ethyl chloride spray, as reported by Kraus, is usually more effective. The painful areas are sprayed intermittently for several minutes (30 to 50 c.c.) but without actual freezing, and pendulum exercises are begun immediately. The local anesthetic effect causes the muscle spasm to relax, permitting the exercises, which are the most important part of the treatment.

Massage of the bursal region is likely to increase the pain in most cases, though gentle massage of the adjacent muscles may be used to maintain muscle tone. Manipulation or stretching usually increases pain and spasm, and often does more harm than good. Stretching under anesthesia is particularly apt to be disastrous, as the inflamed or degenerated tissues are fragile and easily injured, and it is these tissues rather than "adhesions" that are torn. Relief is sometimes obtained with manipulation, however, by rupture of the cavity.

*Exercises* are of great value, and are the most important of the various physical therapeutic measures. They may be used independently at certain stages, or in conjunction with the spray, irrigation, puncture, or operation. Exercises should be active rather than

Fig. 7.

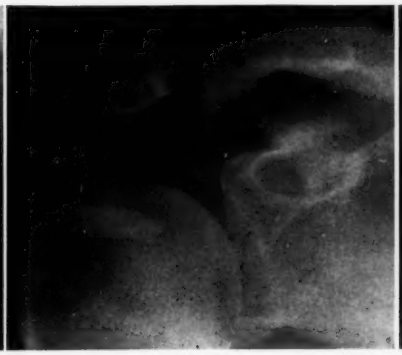

Fig. 8.

Fig. 9.

Fig. 7. Large calcification in infraspinatus tendon, seen well in lateral view of humerus with arm abducted. A good view for this tendon, and for the subscapularis. Pain for 4 days, following lifting. Operation released thick, milky fluid with calcareous granules in bulging tendon. Tendon degenerated. Relieved.

Fig. 8. Large calcification in subscapularis tendon (superimposed on femoral head) as seen in external rotation. Pain for 1 year. No relief with diathermy. Operation: Several hard white nodules in tendon with soap-like material under pressure. Three communicating cavities. Result excellent for 2 years.

Fig. 9. Large, single calcareous deposit in supraspinatus tendon. Pain for 4 years. Worse after diathermy, and after irrigation. At operation 2 cubic centimeters of milky fluid under tension was released. Granules infiltrated the degenerated tendon. Result for a period of 3 years was excellent.

passive, although the arm may be supported at times to reduce the effect of gravity. They should be done slowly and gently, within pain limits, in the most favorable positions. They should be graduated, first with assistance, then against gravity, and finally against resistance.

The pendulum exercises are the simplest, easiest, and least painful; they should be done with the arm in flexion and hanging loosely, i.e., with the trunk flexed, or with the subject lying prone upon a table with the arm over the side. The arm is swung gently from the shoulder, back and forth, and from side to side, and in a circle, and rotated. Next, the arm may be rotated, with the subject in the supine position, and abducted, preferably on a polished surface. The wall-creeping exercise, in flexion, and in abduction, may follow. Assistance may be gained by using a light bar, rope and pulley, or the spokes of a large wheel mounted vertically. Similar exercises may be performed under water, with the buoyancy of the water for support.

Radiotherapy sometimes relieves the acute attacks, but has little effect on the chronic ones. Absorption of calcium salts may follow in the early acute cases, but usually does not occur in the chronic type. Repeated or intensive roentgen radiation is undesirable, as it may increase the degeneration of the diseased tissues, or burn the skin.

Novocain injection gives temporary relief, which may be prolonged by the drainage through the needle punctures. Novocain iontophoresis is reported[1] to give relief in some cases.

*Aspiration, irrigation, or puncture* of the calcified area may give relief, chiefly by the release of tension. It is necessary, for success, that the needle enter the cavity, that it be large enough and the contents liquid enough to flow through the needle. Aspiration or irrigation of the bursa is helpful only if there is fluid in the bursa, which is rarely the case. The needles must usually enter the cavity in the tendon in order to have any effect, even when the contents are liquid. Improvement occurs by drainage of the liquid to the outside or into the bursa, where it is absorbed. The cavity can usually be entered by accurately locating the tender spot. Fluoroscopic control may be more precise, but aseptic technique cannot so easily be maintained, and there is danger of roentgen burns of the operator's hands on repeated exposure. It is desirable to wash as much of the calcified mate-

[1]Personal communication, Kraus and Snow.

rial out of the tendon as possible. Failure is due to using a needle that is too small, missing the cavity, or the contents being too dry and firm. Successful aspiration, irrigation, or puncture, is simple, safe and effective, not only in relieving pain, but also in removing the calcareous material, and the results, immediate and late, are good.

### OPERATION

*Operative drainage of the calcified cavity* in the tendon offers the surest and most permanent relief of any type of treatment, and is often the best or only method of removing the calcareous deposit. Consequently, immediate relief of pain and spasm, and permanent healing of the lesion are obtained with operative treatment in a higher proportion of cases than with any other treatment.

A short incision is made anteriorly below the acromion, and the fibers of the deltoid muscle split near its medial border, thus exposing the bursa. The bursa is opened and inspected. The soft white areas with surrounding erythema in the floor of the bursa, locate the lesions. The whole floor may be inspected by rotating the arm and retracting the wound in various directions. Each area is incised in line with the fibers of the tendon, thus releasing any liquid which may be present. The more solid portions are lifted out with a curette, or dug out with the point of the scalpel. The loose or degenerated strands are excised. The defect is sutured in so much as this will bring the edges closer together. The bursal incision may be loosely approximated, likewise the deltoid muscle.

### POSTOPERATIVE CARE

A sling and swathe are used at night if necessary for protection. The arm was suspended in slight abduction and neutral rotation in some cases, but this is not necessary. Exercises are begun the day after operation, at which time the motion is often better than before operation. Exercises are progressive, according to the amount of pain and spasm. Ethyl chloride spray may be used for relaxation in the occasional case with considerable pain and spasm after operation. The sutures are removed in 5 to 7 days, and underwater exercises may be begun as soon as the wound is healed. The infra-red lamp and gentle massage may be used as indicated.

There is usually immediate relief of the preoperative pain, especially in the acute and severe cases. Pain due to the incision is usually slight and subsides in 2 or 3 days. Motion returns to normal in a week or two in the cases with liquid material without infiltration. Motion improves more gradually in the shoulders with multiple, or gritty, infiltrating calcifications, requiring 2 months or sometimes longer for return to normal.

### RESULTS

We have operated upon 23 shoulders (22 patients) with calcification of the tendon cuff at the shoulder in the past 6 years. Eighteen were followed from 3 months to 6 years, an average of 19 months. Most of these shoulders had previously been treated with physical or radio therapy without relief. Those with no pain, weakness, disability, or limitation of motion were considered excellent results. Those considerably improved, but with slight or occasional symptoms, were considered good results.

There was immediate and continued relief of pain, and improvement in motion and use of the shoulder in all cases. The result of the followed cases was excellent in 5, good in 10, and fair in 3. The contents of the cavity were liquid in 4 of the excellent result shoulders, whereas they were dry and gritty in most of the good results, and 2 of the fair ones. The other fair result had a manipulation of the shoulder just before the operation, at which "adhesions were torn."

The excellent results in the liquid content shoulders were better and more quickly obtained than in similar cases in which patients were treated by puncture or irrigation, 2 being failures after treatment by irrigation. The results for the shoulders with dry or infiltrating lesions were much better than the results in similar cases in which patients were treated by irrigation or puncture, physical therapy, or radiotherapy. One had been treated by irrigation, 10 by diathermy, and 2 by radiotherapy, without improvement, and some had become worse. Five of the tendons with liquid

contents had been treated with diathermy, 1 with radiotherapy, without relief.

Thus the improvement with operation was usually obtained more quickly and more surely, while the eventual result was often better, than with any other form of treatment.

### PROPHYLAXIS

It appears that degeneration and calcification in the tendon cuff of the shoulder is due to attrition and circulatory damage. *The use of the arm at the side, a sequence of the evolution and civilization of man, has produced a mechanical disadvantage and increased the wear on the tendon cuff.* The lesion might be prevented or reduced in severity by avoidance of the use of the arm in this position, especially for jerky, forceful, tense, or resisted motions in abduction or external rotation. Correction of the position and manner of use of the arm and the posture of those persons with contributory occupations, should largely prevent the lesion. Warming-up the muscles before use, and keeping them in good physical condition by regular moderate exercise also should aid in the avoidance of this condition.

### SUMMARY AND CONCLUSIONS

The symptoms, signs, roentgenographic appearances, and etiologic factors in one hundred cases of calcareous degeneration in the tendon cuff of the shoulder are reviewed. The pathology of the 23 shoulders operated upon is described. The results of treatment by physical therapy, radiotherapy, novocain injection, aspiration, irrigation, or puncture, and of operative removal of the calcareous material, are reported.

Calcareous degeneration in the tendon cuff of the shoulder is a frequent and disabling lesion. The accompanying subdeltoid bursitis is a secondary condition. The symptoms and signs and the roentgenographic features of this lesion are characteristic. The degeneration is probably due to attrition from the use of the arm at the side with repeated sudden, jerky movements. It may be prevented by avoiding such motions.

The calcareous material is suspended in liquid in the early acute cases, and the roentgenographic shadow is cumulus cloudlike and fairly homogeneous. The deposit is granular and infiltrating in the chronic cases, and the shadow is fragmented and irregular in outline and density.

Relief from pain and spasm, and absorption of the suspended calcareous material, may often be obtained in the early acute cases by rest, heat, diathermy, cold, ethyl chloride spray, or radiotherapy. The chronic cases usually are not helped.

Massage, stretching, or manipulation are likely to increase the pain, spasm, and limitation, and to damage the shoulder.

Rupture of the calcareous deposit into the bursa, spontaneously or with treatment, will give immediate relief.

Aspiration, irrigation, or puncture may relieve pain when thereby the material is drained and the tension reduced. Novocain injection relieves pain only temporarily unless the cavity is drained at the same time.

*Operative removal of the calcareous deposit is the surest and quickest method of relief*, particularly in the chronic cases. Complete removal of the deposit is desirable for best and permanent healing of the lesion.

Special exercises should be used with any of the treatments, for preservation and restoration of motion and strength in shoulder and arm.

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# THE FUNCTIONAL PATHOLOGY OF EXPERIMENTAL FROSTBITE AND THE PREVENTION OF SUBSEQUENT GANGRENE

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THE problem of tissue damage after exposure to severe cold is particularly timely since the number of cases of gangrene and death is increasing with the intensification of the war effort. Accordingly it seemed important to follow the effects of experimental and accidental exposure to low temperature by means of the fluorescein method which we reported some time ago (6, 7, 8).

The tissue changes occurring in frostbite have been carefully studied by German observers (4, 11), by Lewis and by Greene. These investigations have been summarized excellently by Bigelow in a recent survey so that a detailed review is unnecessary. However, a brief summary of the available facts seems warranted.

Exposure to severe cold in the absence of marked dampness causes an immediate slowing of the blood stream owing to strong arteriolar constriction. Oxygen exchange ceases since the dissociation of oxyhemoglobin at low temperatures is negligible. If the cold is sufficiently intense, the frozen limb solidifies completely. This happens at a temperature lower than anticipated due to the effect of "supercooling." In man as well as in experimental animals, the skin becomes very white, a state which persists until thawing starts. A biopsy during this stage fails to reveal any essential change in the tissue save for the extreme contraction of the arterioles; this may be greater *in vivo* than in biopsies. Immediately after thawing the skin may remain pale. This may be explained by persistent arteriolar spasm since biopsies obtained at this time fail to reveal any structural reason for the lack of circulation. A fluorescein test performed at this time shows an arrest of circulation with absence of fluorescence in the area previously cooled. In ½ hour after exposure, the skin becomes bright pink. Apparently some substance forms during the exposure and causes maximal capillary dilatation. Subsequently swelling of the exposed area produces a considerable increase of size. After an indefinite time the swelling subsides and complete healing occurs or gangrene begins, initially as blue-brown areas of discoloration and subsequently in all the exposed areas.

During this phase our own biopsies and those of many other observers (1, 3) show the following characteristics: After 24 hours the endothelium of the arterioles is swollen and spongy. The lumen of many vessels contains clumps of red blood cells with no tendency for them to adhere to the wall or to organize. The structure of the erythrocytes is intact. Much later, 72 hours or more, real thrombosis develops; this may be due to massive infection which occurs almost always in severe frostbite, unless great care is taken to prevent the invasion of bacteria. At this time the tissue cells stain poorly and cell membranes undergo dissolution. Later, all differential staining qualities are lost and many vessels are filled with clumps of red blood cells or thrombi. The photographs of Greene show this in a superlative manner. It is undecided whether the clumping, called stasis (10), or "silting" (3) results from loss of plasma into the tissues and stranding of the red blood cells or from colloid chemical changes. The problem was not deemed essential in the present studies since fluorescein affords a clear insight into the physiology of these vessels.

*Mild cold.* Six normal individuals were chilled mildly by immersing the arm up to the

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elbow for 8 minutes to produce a skin temperature of 10 degrees C. At this time 10 cubic centimeters of a solution containing 5 per cent fluorescein and 5 per cent sodium bicarbonate were injected intravenously and the lights of an otherwise dark room were extinguished. The cooled area, bright pink in daylight, is exposed to the special ultraviolet light which causes fluorescein to emit its specific golden-green fluorescence. The cooled area shows a marked diminution of fluorescence in comparison to normal skin as long as the temperature of the exposed area is reduced. The examination of capillary blood removed from an area of diminished staining shows that it contains as much fluorescein as blood in other parts of the body. This fact suggests that the dye cannot diffuse from the cooled capillaries into the interstitial spaces in the same way as in unaffected areas of the skin. This may be due to decreased capillary permeability or markedly decreased filtration pressure. In respect to filtration pressure it should be noted that neither local anesthesia nor sympathetic block changes the picture. A patient with a complete transverse lesion of the spinal cord (6th dorsal) showed an identical reaction when his feet were exposed to cold. If arteriolar contraction were induced by an axon reflex and would thus decrease filtration pressure and thereby diminish tissue staining, it is difficult to understand why large doses of nitroglycerin or amyl nitrite sufficient to cause a marked fall of blood pressure do not change the picture. Even a decided increase of intracapillary pressure by the application of a blood pressure cuff with a pressure of 70 millimeters of mercury proximal to the cooled area and the augmented venous pressure induced fails to alter the picture. Therefore, one is forced to assume that the first reaction to cold is a decrease in capillary permeability with parallel arteriolar contraction to decrease filtration pressure. This might be interpreted as a defense mechanism which prevents water from entering tissue spaces and averts tissue bursting at freezing temperatures. The same results were obtained in 11 rabbits when mild cooling was induced in previously depilated areas. A detailed report of these observations was published elsewhere (5).

*Freezing.* In 6 rabbits severe cooling was produced by applying beakers, 3.7 centimeters in diameter and filled with dry ice, to the depilated skin of the abdomen for periods ranging from 5 minutes to 90 minutes. Ordinarily 5 beakers were applied in an experiment and the intervals were so arranged that the end of the cooling period was simultaneous for all. This permitted simultaneous observation of the vascular effects after varying degrees of damage.

Seventy-five one-hundredths of a cubic centimeter of the aforementioned fluorescein solution were injected intravenously immediately after a cooling period. At this time all exposed areas were frozen "stiff." The entire abdomen becomes intensely fluorescent under long wave ultraviolet light save in the areas exposed to cold; the latter remain deep purple indicating their complete exclusion from the circulation. At intervals varying from 7 to 58 minutes and depending upon the duration of exposure as shown in Table I, all areas become fluorescent. This event occurs a *considerable time after* the tissue has thawed. Fluorescence in the cooled areas slowly becomes more intense than in the surrounding areas and finally they are decidedly hyperfluorescent in comparison to the normal tissue. The picture closely resembles that of an inflammatory area. The marked staining is the result of increased capillary permeability subsequent to the anoxic phase of freezing. Complete *fluorescence was always temporarily restored in an exposed area* despite extreme exposure to cold. Then, previously frozen areas begin to swell and they present a bright pink color in daylight.

Since fluorescein is excreted rather rapidly, the test can be repeated after 12 hours. At this time, the picture has usually undergone a complete change. Areas frozen for short periods show a fluorescence like that of the other skin. If the area has been exposed for a long period, patches of nonfluorescent skin are seen and indicate a pregangrenous state. These patches may not be detected in ordinary daylight.

After 72 hours, the part exposed to freezing temperature for long periods, again shows complete nonfluorescence just as it did immediately after freezing. This fact indicates vascular occlusion which will result in gangrene.

Biopsies from such nonfluorescent areas show arteriolar stasis with packed red blood cells and loss of differentiation of the cell elements as prominent features.

Since most severe exposure with solidification of tissue is always followed by a period of complete restoration of circulation for a period of 6 hours or more, it seemed promising to attempt to prevent the formation of clots by heparinization subsequent to exposure. This was done in 5 rabbits of corresponding weight and, for the most part, from the same litter as the controls. They were chilled with dry ice in the manner described earlier. Five other rabbits served as controls. The treated rabbits obtained 3 cubic centimeters of heparin (10 milligrams per cubic centimeter) intravenously every 12 hours beginning ½ to 3 hours after freezing ended. These injections were continued for at least 5 days.

Superficial gangrene involving the entire thickness of the skin but not the underlying fascia was obtained regularly in all exposed areas of untreated controls when the exposure to dry ice lasted more than 15 minutes. Some developed partial or extensive gangrene with shorter exposures.

In the group which received heparin, clotting time was determined by the Lee-White method; it never went below 22 minutes in any animal. The swelling of the previously exposed areas was constantly greater in this group than in the untreated animals. The exposed areas remained fluorescent and gangrene did not occur. Two animals did show small superficial areas of necrosis within the exposed area after exposures of 45 and 60 minutes, respectively.

Nevertheless all animals showed a marked susceptibility to infection of the previously frozen area, especially when gangrene did not develop. Tightly applied sterile dressings from the outset and reapplication under absolutely sterile conditions, as employed successfully in the treatment of burns, solved this problem. In subsequent experiments the exposed area was painted with an aqueous solution of merthiolate and the sterile dressings were coated with 5 per cent sulfathiazole ointment in order to prevent infection of the oozing tissue from occurring.

TABLE I.—DEPILATED SKIN OF RABBIT ABDOMEN EXPOSED TO FREEZING BY CONTACT COOLING WITH BEAKERS FILLED WITH DRY ICE

| Time of exposure to beakers filled with dry ice Min. | Time of spastic vascular occlusion after exposure Min. | Time of complete restoration of circulation until onset of vascular occlusion Hours | End-result |
|---|---|---|---|
| 5 | 13 | No occlusion | Healing |
| 15 | 22 | 18 | Small areas of gangrene |
| 30 | 50 | 11 | Gangrene of exposed skin |
| 60 | 90 | 7 | Gangrene of exposed skin |

Encouraged by these apparently good results we exposed the depilated hind leg of 22 rabbits to severe cold while the animal was under nembutal anesthesia. The hind legs of the animals were covered to the knee by a boot of condom rubber and great care was taken to avoid any constriction. The prepared legs of 2 animals were then dipped simultaneously into an alcohol bath of —12 degrees to —20 degrees C. for a period of 45 to 90 minutes. This cooling period corresponds to a much longer one in cold air for the convection of heat by alcohol is many times that of air. The thin layer of rubber made it, for practical purposes, a contact cooling. In 5 to 8 minutes the submerged portions of the legs were frozen stiff. One animal of each pair was untreated while the other was heparinized. Among 11 heparinized animals, 9 recovered completely in so far as tissue loss was concerned; two developed a superficial necrosis of considerable extent 3 days after exposure but they did not lose the leg. Two animals died from severe internal hemorrhage on the 4th and 5th day, respectively, after exposure. Their clotting times had gone to 16 and 18 hours.

All animals of the untreated group developed complete gangrene of the exposed leg with spontaneous amputation which included the bone.

All animals of both groups had an initial motor and a sensory paralysis of the exposed area except one of the heparinized group. Three of the heparinized frostbitten animals recovered motor and sensory function in about

2 weeks while another had complete loss of sensation, as tested by pinprick, for a period of nearly 4 weeks.

In 2 of the heparinized group in which superficial gangrene occurred, the moderate pressure from adhesive applied to one area might have been responsible. All animals of the heparinized group displayed full fluorescence of the damaged leg in each test throughout the period of observation.

Accordingly complete gangrene of the tissue following severe experimental frostbite in rabbits can be prevented by heparin. The great danger associated with this treatment seems to be the marked susceptibility of damaged but surviving tissue to infection. Nerve tissue seems rather sensitive to cold and is less liable to survive, without injury, severe exposures. This may explain the persistent paresthesias and hyperesthesias after frostbite not attended by loss of tissue.

In 4 animals a pressure bandage was applied after exposure to cold. Two of them received heparin as well while the remaining 2 were treated only by a pressure bandage. The result in the heparinized animals was the same as without pressure bandage whereas the animals treated by pressure bandages alone developed a rapidly spreading, extensive gangrene like that seen in animals with ordinary dressings.

*Clinical evidence.* The value of the fluorescein test in estimating the extent of damage in patients with recent exposure to low temperatures was demonstrated in 14 cases of frostbite. Thanks to the collaboration of Dr. Edward Bernecker, commissioner of hospitals of the City of New York, we succeeded in obtaining these patients from various New York hospitals immediately after they sought aid. The earliest was under treatment 7 hours after exposure and the latest was 48 hours. All cases occurred in February, 1943, during one night when the weather suddenly turned very cold and a strong dry wind was blowing. There were 13 males and 1 female. The men were frostbitten while working on the docks; the woman was exposed while waiting for a bus. Five men had lesions of the hands as well as feet and 3 also had frostbitten ears. The woman had her most severe injury in the feet.

All patients were subjected to a fluorescein test immediately after admission. The results of these tests were carefully recorded and compared with the final tissue damage noted after an interval of several days. Since the studies with heparin had not advanced sufficiently at that time, no patients were treated with it. If the fluorescein test is done within the first 12 hours, it does not perfectly reflect the tissue damage which may be anticipated. In 4 patients practically all the exposed tissue fluoresced fairly well indicating that the vessels were open at this time. Twenty-four hours later, these patients showed large areas of nonfluorescence after the intravenous injection of fluorescein and these areas corresponded exactly with the loss of superficial tissue which occurred during the subsequent period of observation. If patients are seen 14 or more hours after exposure the fluorescein test reveals exactly the amount of superficial tissue damage to be expected. In 2 patients seen 14 and 16 hours after exposure, a novocain block of the lumbar sympathetic ganglia was performed without any change in the fluorescein pattern indicating that no essential part of the circulation was blocked by spasm. One observation seems important. The fluorescein test indicates the tissue damage expected in the *superficial* layers. While this is a fairly good indicator of the vascular status of the deeper vessels in occlusive vascular diseases, this does not hold for frostbite. In frostbite there may be extensive loss of surface structures despite little or no damage to deeper structures. Among the 14 cases only 1 required débridement of 2 toes while others had complete tissue restoration. It can scarcely be overemphasized that greatest conservatism is in order in respect to surgical intervention after frostbite. The ability of deeper tissues to regenerate is excellent after frostbite and the surgical principles employed in occlusive vascular disease are not applicable to cases of frostbite.

Like Davis and his collaborators we were unable to predict which cases would develop blisters and which would remain dry. Of the 14 cases, 11 developed large vesicles. The content of these blisters after the fluorescein test seems to provide a good indication of the

status of the deeper tissues. Fifteen minutes after the injection of fluorescein, the amount of dye present in the blisters was large in all cases although the surrounding skin did not fluoresce. In 1 case the content of the blisters was free of fluorescein, and this patient lost both toes on which the nonfluorescent blisters were located.

The functional pathology of animals, exposed to severe cold and of patients suffering from frostbite seems to be the same. Since tissue loss can be averted in experimental animals by the use of heparin early after the exposure, this method holds promise in cases of frostbite.

SUMMARY

1. The tissue alterations after exposure to severe cold are described and the sequence of events as well as the vascular occlusion due to stasis is discussed.

2. The sequence of functional changes after exposure to *mild* cold, as elicited by the fluorescein test, is described and emphasis placed upon the arteriolar spasm and decreased capillary permeability.

3. These vascular changes are independent of central nervous system influences and seem to occur by axon reflexes.

4. Cold sufficient to solidify the exposed tissues causes a complete interruption of circulation during the exposure. This is always followed by a period of complete restoration of circulation and increased capillary permeability as evidenced by the fluorescein test. This period lasts for 6 to 16 hours after exposure. This is the most promising period for therapeutic endeavors.

5. The period of circulatory restoration is followed by one with arteriolar and capillary occlusion resulting from the formation of red blood cell clots. Gangrene of the associated area is the consequence.

6. Heparin administered during the period of circulatory restoration prevented gangrene in 16 rabbits whereas all controls had complete gangrene of the part. Five animals were exposed by freezing small areas; in the remaining animals the entire hind leg was frozen.

7. Although tissue loss was averted by the early use of heparin, sensory and motor nerve paralysis was often not prevented.

8. Fourteen cases of human frostbite show that the fluorescein test permits the exact prediction of subsequent superficial tissue loss provided certain precautions are taken.

9. Great surgical conservatism is in order in frostbite since these lesions show a marked tendency to heal. Moreover, the rules for amputation in occlusive vascular disease are not applicable in frostbite.

10. After an injection of fluorescein the dye content of the blisters seems to afford a good insight into the vascular damage in the deeper structures.

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# ACUTE PUTRID ABSCESS OF THE LUNG

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THIS paper is based on the 172 cases of acute putrid abscess of the lung which have been subjected to operation in the past 16 years at the Mount Sinai Hospital. Since there have been but 4 deaths in this series of cases operated upon in accordance with a definite plan, the operative procedures which have been advocated and employed can be regarded as well established and safe. In view of the fact that usually these cases are seen only in the preoperative and early postoperative phases, one of the two purposes of this presentation is to report on the late anatomic and functional results of operation. The other is to survey the essential features of the disease on which the one stage operation has been based.

The concept of acute putrid abscess of the lung as a surgical disease and the related evolution of surgical treatment are based on (1) an understanding of the pathology of acute pulmonary abscess with special reference to surgical features, (2) the application of roentgenography to the diagnosis and more particularly to the exact localization of pulmonary abscesses, (3) the development of a one stage operative procedure, (4) the evidence that consistently good and lasting results are obtainable by such an operation.

Occasional references in the literature indicate that there has been some general acquaintance with the pathology of putrid pulmonary abscess but it remained for the thoracic group of our hospital to present a clear picture of the pathology with special reference to surgical features. Since 1932 the pathology of acute putrid pulmonary abscess has been set forth by members of the group because it gradually became evident that treatment, particularly surgical treatment, had to be related directly to the pathology of the disease. Although all the features have not as yet been generally conceded to exist, I believe that the following essential ones now are rather widely accepted. Omitting the rare metastatic form (which has its own distinctive features) all putrid pulmonary abscesses can be assumed to be due to aspiration of infective material. There is set up a gangrenous bronchopneumonia in the involved bronchopulmonary segment. Liquefaction occurs in a few days and an abscess is formed within a week or 10 days of the onset of the pulmonary infection. The brief period of evolution should be stressed in order to dissipate a belief which still prevails that the gangrenous pneumonic lesion is diffuse and often is only partially liquefied for a period of several weeks or longer. The abscess usually is fully developed within 2 weeks. In most cases an acute abscess is of substantial proportions and thus accounts for the common initial expectoration of a considerable quantity of foul pus. The abscess is single and spherical, is always situated superficially within the pulmonary lobe, and abuts on the thoracic parietes. The shell of lung between the abscess and the pleural surface usually is thin, compressed, and avascular. The abscess cavity is well demarcated from the beginning. Its contents are foul air, pus, and débris, and, in the early stages, fragments of gangrenous lung. The interior of the cavity is smooth at a surprisingly early stage. There are present invariably the orifices of one or more bronchi. The feature of perhaps greatest surgical moment is the constant occurrence of well defined pleural adhesions over the abscess which usually seal off effectively the free pleural space. These adhesions are visceroparietal in the great majority of cases, bind the abscess to the thoracic parietes, and render it readily accessible for safe surgical entry. In a small proportion of cases the abscess faces a fissure, the diaphragm, the mediastinum, or the pericardium. Under these circumstances there are also overlying adhesions which, however, are local and may not extend to the parietal pleura. It is probably this variety of abscess which has led to the erroneous concept of "central abscess of the lung."

Address delivered to the House Staff of the Mount Sinai Hospital, July 10, 1944.

Early in our studies it became evident that a differentiation between acute and chronic abscess was necessary. It was noted repeatedly that the abscess usually retained for a period of several weeks the characteristics I have outlined. Towards the end of, or after, 6 weeks, additional lesions usually appear: multilocularity, spread of infection by spill-over, interstitial pneumonitis, fibrosis, bronchiectasis. These are the features which often render the results of surgery less satisfactory in respect to mortality, morbidity, and cure. Accordingly we decided to term all abscesses acute if of less than 6 weeks' duration, with the idea of solving the problem of putrid pulmonary abscess within that period. Obviously this is a rather arbitrary classification and we, like others, have noted that occasionally abscesses remained simple after 6 weeks or on the other hand became complicated in a few weeks. Nevertheless it appears to be the best classification at least from the viewpoint of therapy, for our results have been decidedly less satisfactory in the second 6 weeks' period (that of subacute or subchronic pulmonary abscess). Other classifications have been proposed of which the most popular appears to be the division into simple and complicated abscess based on pathology. It is difficult to determine where the line should be drawn in such a classification. Furthermore, emphasis is omitted on the aspect of therapy in the acute stage and no advantage is offered other than a statistical explanation of good versus poor surgical results.

Related to the question of classification is that of the indication for operation for acute abscess of the lung. Not all patients with acute putrid abscesses who enter this hospital are operated upon, but it can be said that operations have been more often performed in recent years because consistently good results were observed. The indications for operation for acute abscess may be imperative or elective. Among the former are patients with hyperacute manifestations (severe toxicity), unusually large abscesses, and abscesses which appear to be on the verge of invading or have already invaded the pleura. In a substantial proportion of cases the indications are elective. These are cases of small abscesses which remain stationary or increase in size after a period of observation, abscesses in which cavities drain poorly (roentgen evidence), patients with sustained fever or intensely fetid sputum, cases in which there is diabetes. Not all elective indications need be enumerated and it can be stated that spontaneous subsidence might have (would have?) occurred in some of the patients who have been subjected to operation.

The application of roentgenology to the diagnosis and especially to the exact localization of an acute abscess represents the essential basis for correct surgical management. After it was learned that films revealed the characteristic feature of pulmonary abscess (cavity with a fluid level) in no more than half the cases, that only a circumscribed area of dense "pneumonic" infiltration existed in some cases, and that areas of rarefaction might or might not appear in the midst of such infiltration during observation, it became evident that the diagnosis of pulmonary abscess often could not be made on films alone. On the other hand, studies of films always made possible a precise localization of the abscess. Hence every effort was bent in the latter direction in order to determine in any given case the site at which the abscess abutted on the thoracic parietes, and thus the site at which the abscess could be entered safely through adhesions. Theoretically a study of films taken in various positions including the oblique should provide the required information. Actually there are not infrequently errors in interpretation, particularly when abscesses are situated laterally on the bend of the thoracic cage. Adding to the foregoing the difficulty in counting ribs accurately it became apparent that a marker for precise localization was required. This was provided by the "spot" method introduced by Rabin, which is employed immediately before operation. A mixture of methylene blue and iodized oil is injected into the intercostal musculature at the assumed place (often determined fluoroscopically) of contact between the abscess and the thoracic wall. Films in appropriate positions are taken and the relationship of the iodized oil to the abscess is seen. The methylene blue in the musculature is exposed at operation in order to locate the situation of the

radiopaque oil which was injected. The relationship of the oil to the abscess being known, the operative exposure of the abscess is performed in accordance with the relationship of the "spot" to the roentgen shadow of the abscess. Thus the "spot" may be immediately over the abscess or as much as an inch from the site of contact between abscess and parietes. In the rare instances in which the method has failed the reason was to be found in an error in technique (failure to inject the intercostal musculature). The Rabin "spot" method can be employed with advantage in all cases but in any event should be used whenever the exact place of contact of the abscess with the thoracic parietes is in doubt. Emphasis should be placed on its use in seriously ill patients because the abscess should be entered with minimal dissection in such cases.

The development of the one stage operative procedure was based on the realization that a pulmonary abscess is characterized by a superficial position with overlying adhesions and that the essential pathology is constant. Many operations performed in our clinic have established the correctness of both points. They have also disclosed errors which required correction. Thus, when adhesions are not encountered one can be quite sure that the site of surgical approach is not correct. Again, if the abscess is not found by exploratory aspiration superficially in the lung, the needle has been introduced at an incorrect point. With the full knowledge of the pathology and with lessons gleaned from errors like the foregoing, the logic and desirability of the one-stage operation became more and more apparent. We proceeded in a direction diametrically opposed to the two stage operation which was and still appears to be rather generally practiced. The two stage operation is based on the assumption that liberal exposure of the abscess is required and that adhesions if present are not apt to be sufficient to prevent contamination of the free pleural space when the abscess is drained. The so called "central" abscess also figures in the two stage operation. The disadvantages inherent in the two stage operation need not be set forth. It is not amiss to state, however, that a two stage operation is preferable to a one stage procedure which is not based on precise roentgen localization of the abscess. There has been no change in the principles of the one stage operation which we have been performing for 16 years or longer. In brief, they consist of the exposure of pleural adhesions by a limited excision of a segment of one rib (in most cases), incision through adhesions at their densest portion (at which place the bulge of the abscess will often be noted), disclosure of the abscess by aspiration, its unroofing by excision of the thin compressed shell of overlying lung, and the visualization and gauze tamponade of the abscess cavity and all its recesses. In a small proportion of cases parietal adhesions will be scanty or absent (interlobar abscess, etc.). Under these circumstances the one stage operation is carried out by suturing normal lung around the abscess to the thoracic parietes, and, after the free pleural space is securely shut off, by entering and unroofing the abscess. The principles of operation remain the same whether an abscess is either single or multilocular, and whether the patient is either seriously or mildly ill.

There is scarcely any surgical experience which compares with the dramatic result which is seen in virtually all cases following the one stage operation. In a patient who often is toxic or septic, and expectorating fetid pus, cough and expectoration cease promptly, fever subsides, and the general appearance is one of great improvement. Indeed, the continuation of symptoms of pulmonary abscess such as the expectoration of foul sputum is evidence that the pulmonary abscess has not been adequately cared for at operation. The immediate results of operation thus are excellent. Concerning the 4 deaths in 172 operative cases at least 2 are ascribable to errors in technique and probably were avoidable. Hence the mortality of operation for acute putrid pulmonary abscess should be ascribable to the operation and only rarely to the disease. Few secondary operations for drainage of adjacent areas of pulmonary suppuration or for empyema have been required in recent years due to improvement in methods of localization of the abscess as well as in the technique of operation. The

rapid recession of clinical manifestations usually is attended by roentgen evidence of subsidence of the inflammatory reaction around the abscess cavity. The latter soon becomes clean and presents on its floor the orifices of one or more bronchi. The chief problem after operation has been the maintenance of the pulmonary cavity and, more particularly, of the bronchial fistula. The tendency is to permit the fistula and the wound to close too soon. Experience has shown that the bronchial fistula should be maintained until the patient is entirely symptom-free and pulmonary infiltration (x-ray evidence) has virtually disappeared. In this postoperative period, usually of 4 to 8 weeks' duration, the wound requires meticulous attention to detail.

The follow-up which now extends over a period of 16 years reveals that recurrence of pulmonary abscess rarely if ever takes place. The few instances in our series of so called recurrence of putrid pulmonary abscess probably represent persistence of the infection and can be ascribed either to inadequate unroofing at the time of operation or to premature closure of the wound. Most pulmonary cavities heal even when large but there arises occasionally the problem of an unusually large cavity which remains after the unroofing of an abscess. Some of these large cavities heal in time. Others require some type of plastic procedure for their closure. Various methods have been advocated. I have devised a simple procedure, that of free fat transplantation, for the purpose. The results usually are satisfactory but occasionally the graft is extruded or there remains a closed dead space following absorption of the graft.

In any follow-up continued over a period of many years, patients may be well of their disease but die from other causes. Not all the patients who were cured of their abscess are alive today. There have been deaths from a number of unrelated causes (cancer of the stomach, suicide, etc.). There were also 2 deaths following operations for the drainage or closure of ancient cavities left after the primary operation. The follow-up which includes all the operative cases has revealed that the great preponderance of patients not only have healed wounds and show complete healing of the abscess, but also remain symptom-free permanently. Thus the one stage operation can be regarded as entirely satisfactory for acute pulmonary abscess, providing not only a very low operative mortality and good immediate results but also a high incidence of permanent cure.

# GASTRIC RESECTION FOR DUODENAL ULCER

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TWENTY-TWO years ago, the Mount Sinai Hospital group for gastroenterological surgery began to discard gastroenterostomy in favor of partial gastrectomy in the surgical treatment of duodenal ulcer. We had been impressed by Haberer's publication which had shown that gastric resection for duodenal ulcer could be performed with a reasonably low mortality. Furthermore, the frequency of gastrojejunal ulcers after gastroenterostomy (in our material 34 per cent, among these 18 per cent proved by reoperation) had convinced us that gastroenterostomy was an illogical operative procedure. It is a generally accepted fact that gastroenterostomy does not reduce hyperacidity to any marked degree in the vast majority of patients. In addition, each patient has before him the possibility of the development of a gastrojejunal ulcer. Furthermore, it is important to remember that many patients after a gastroenterostomy continue to complain of gastric distress, although they are not suffering from a gastrojejunal ulcer. I feel certain that not more than about 20 per cent of the patients suffering from a nonobstructive duodenal ulcer are permanently free of symptoms following gastroenterostomy. 80 per cent of failures should condemn any operation.

A number of years before Haberer's publication, the well known British surgeon Bland-Sutton, in a Hunterian lecture, pointed out that, in the presence of an open pylorus, gastroenterostomy would not cure a duodenal ulcer. "With an unobstructed pylorus, gastroenterostomy cannot be relied upon to cure a chronic duodenal ulcer, and as it exposes the patients to the discomforts and risks of regurgitant vomiting of jejunal ulcer, I have gradually abandoned it as a routine method and prefer to excise the pylorus and the segments of the duodenum containing the ulcer."

In other words, Bland-Sutton suggested pylorectomy combined with removal of the ulcer-bearing area of the duodenum rather than gastroenterostomy, in the treatment of unobstructed duodenal ulcer. However, Haberer went a step further. He showed that, in order to attain permanent relief of symptoms, removal of at least half the stomach rather than pylorectomy was advisable. This more radical operative procedure was supported by the work of Lorenz and Schur who had shown that extensive resections of the stomach were necessary in order to effect a marked reduction of the preoperative hyperacidity.

Hyperacidity and duodenal ulcer are closely interwoven. If we had some drug at our disposal which would make a hyperacid stomach anacid without destroying the gastric mucosa, we would have a simple nonoperative solution for the cure of nonobstructing duodenal ulcer.

It must be admitted that gastric resection, while far superior to gastroenterostomy, does not cure every patient suffering from duodenal ulcer. A small percentage seems resistant to any form of surgical therapy. Their number is not large, however, and should not reach above 5 to 10 per cent following a properly executed gastric resection. However, because of this small group of failures, in contemplating the overall picture of partial gastrectomy for duodenal ulcer, it would be most unreasonable to consider discarding the operation.

The extent of the gastric resection has been gradually increased, because there seems to be a close relationship between the amount of stomach removed and the postoperative results. Originally surgeons, who encountered a duodenal ulcer in a very movable duodenum, would remove the pylorus and the first part of the duodenum (v. Rydygier, Bland-Sutton). In other words, they performed a pylorectomy. It was soon found, however, that neither pylorectomy nor antrumectomy (the next step) produced any marked reduction in the gastric acidity. For this reason the gastric resection was extended beyond the reentrant angle (partial gastrectomy) or even to

a level close to the cardia (subtotal gastrectomy).

I am amazed at the frequent abuse of the term "subtotal gastrectomy" for duodenal ulcer. The classification "subtotal gastrectomy" implies that the upper line of resection is located near the cardia and that the lower line reaches below the duodenal ulcer. Practically no gastric resection for duodenal ulcer reaches as far as the cardia. The line of transection during gastric resection for duodenal ulcer is situated slightly above the re-entrant angle. It seems that the correct term should be "partial gastrectomy." On the other hand, gastric resections for gastric ulcer are usually subtotal gastrectomies.

I would like to make this point very clear, as it is of greatest importance in the statistical evaluation of late results. It has become the custom for some surgeons in recent years, whenever the ulcer infiltrates the pancreas or is imbedded in extensive adhesions, i.e., whenever the removal of the ulcer-bearing part of the duodenum presents any technical difficulties, to leave the ulcer *in situ* and carry the transection just above, not below the ulcer. Anybody who has operated upon many patients having these complicated conditions knows that, in order to insure a safe closure of the duodenum, the surgeon in attempting to leave the ulcer *in situ*, is often forced to leave part of the pylorus on the posterior wall, even if he does not perform a typical prepyloric Finsterer operation (*Resektion zur Ausschaltung*). Yet these incomplete operations are erroneously called: subtotal gastrectomies. Everybody familiar with the literature realizes the importance of the pylorus in the question of recurrent duodenal or gastrojejunal ulcer. It is obvious that, if these incomplete operations are labelled "subtotal gastrectomies," the follow-up results will be clouded. The operation is accused, whereas the technique is actually at fault. In a typical gastric resection the specimen must show a complete ring of duodenum.

The complete removal of the pylorus in gastric resections is of the greatest importance in obtaining a satisfactory postoperative result. Seventeen years ago, Haberer published a case in which the pylorus had been left *in situ* (Finsterer operation). Subsequently, a number of secondary gastric resections for gastrojejunal ulcers were performed. Finally, the patient was cured, when the pylorus was removed. Similar recurrences may be observed, even if only part of the pylorus is removed at the time of operation.

Resection of the duodenum above the lesion with complete removal of the pylorus is usually feasible in those cases only in which the ulcer is located beyond the first portion of the duodenum and in which it encroaches upon the common duct. In these cases removal of the ulcer would present too many serious technical difficulties to warrant increasing the risk. However, ulcers in this location are fortunately rare. Most duodenal ulcers are resectable when the proper technique of freeing of the duodenum is employed. The recent trend in some hospitals of leaving the ulcers in place should not be encouraged. It represents a make shift procedure rather than a method of choice.

If the line of dissection in the duodenum is carried above the ulcer and not below the ulcer, the operative procedure should be classified as "palliative" resection of the stomach.

Adoption of the operation of partial gastrectomy for duodenal ulcer came about very gradually. Strong opposition was encountered not only from those surgeons who preferred gastroenterostomy because they were unable to perform gastric resections, but also from leaders in the profession. It seemed to me that, when we first tried to introduce this method in this country, we not only found practically no support, but we had to apologize for introducing so radical a procedure. Since then the picture has changed completely and now gastric resection is considered by most surgeons as the method of choice in the treatment of duodenal ulcer.

Here and there we still find small groups who continue to offer resistance. In 1936 Trimble and Reeves stated: "No extravagant claims are advanced for gastroenterostomy. It is not a panacea for all gastric and duodenal ulcers. Nevertheless, it is felt that this operation should be applied in the majority of these lesions, occurring as they do in the pyloric portion of the stomach and the first

portion of the duodenum, and that it is one of the most satisfactory operations in the armamentarium of the surgeon."

Recently Heuer published a careful statistical review based on a study of the gastric and duodenal ulcers at the New York Hospital. He comes to the amazing conclusion that gastroenterostomy is a satisfactory operation not only for duodenal, but also for gastric ulcers. He recommends this method to his students. As his service represents one of the important surgical teaching units in this country, his conclusions should not go unchallenged.

Heuer bases his opinion as to the limited value of gastric resection in the surgical treatment of gastric and duodenal ulcers when compared with results following gastroenterostomy on the very small number of 83 resections for duodenal ulcers and 59 resections for gastric ulcers. In view of the fact that the present popularity of gastric resection for gastroduodenal ulcers is based on the experience collected all over the world on hundreds of thousands of cases, these 142 cases seem particularly insignificant. If we want to revert to the antiquated operation method of gastroenterostomy, one's opinion should be supported by the analysis of a substantial number of patients and not by so small a group. Heuer mentions the small inherent operative mortality of gastroenterostomy and stated that 100 consecutive gastroenterostomies were performed on his service since 1939 without a death. But Duval and Wilson have reported 105 and 93 consecutive cases, respectively of gastric resection for ulcer, without a death. The average mortality of gastroenterostomy is about 2 per cent, just about the same as the mortality following gastric resection. Thus the argument that the mortality of gastric resection, when performed by well trained surgeons in higher than that of gastroenterostomy is fallacious.

Heuer has collected a large number of undifferentiated ulcers, both gastric and duodenal ulcers (12,306 treated by gastric resection and 5,715 by gastroenterostomy) operated upon by different surgeons in different countries between 1935 and 1942 with a quotation of their mortality rates. No references are given. It is quite evident that no conclusions of any value can be drawn from such a statistical study, because operative technique changed materially during this period. The better preoperative preparation of the patient, the introduction of continuous spinal anesthesia, the use of the sulfa drugs, and the recent popularity of blood transfusion, fall into this period (1935–1942). They have reduced postoperative mortalities considerably. Thus it is unfair to compare operative results in 1935 with those in 1942.

Follow-up results after gastric resection for gastric ulcer are excellent. Mage has reported among 98 cases of gastric resection for gastric ulcer performed at Mount Sinai Hospital, one instance of a gastrojejunal ulcer. The patient had repeated attacks of epigastric pain and vomiting. The x-ray examination showed "a small irregular penetration suggesting a lesion in the postoperative stomach." The patient was not operated upon again and was lost from observation after 18 months. In view of the extreme rarity of a gastrojejunal ulcer following subtotal gastrectomy for gastric ulcer, and in view of the lack of substantial evidence, this case should not be included in the group of recurrent ulcers. On the other hand, it is generally conceded that gastroenterostomy for gastric ulcer is an illogical operation and that the follow-up results are most unsatisfactory. I have followed many cases of subtotal gastrectomy for gastric ulcers over a period of 30 years, and I have never observed one instance of gastrojejunal ulcer. Gastroenterostomy for gastric ulcer was discontinued by most surgeons many years before gastric resection was introduced as the operation of choice for duodenal ulcer. No amount of argument, no amount of statistical evaluation will bring gastroenterostomy back in the surgical treatment of gastric ulcer.

It is well known that results following gastric resection for duodenal ulcer do not approach perfection. Yet the results are so far superior to those following gastroenterostomy that the latter operation has been generally abandoned in the resectable duodenal ulcer group. It will never be possible to define which ulcer is resectable and which is nonresectable. An ulcer which appears nonresect-

able to one surgeon might be removed successfully by another surgeon.

It is very difficult to compare late results and evaluate different methods published by different clinics. If a service uses gastroenterostomy in many cases, and reserves gastric resection for ulcers which are easily removable, the mortality should be lower than if gastroenterostomy is the rare exception as an operative procedure. Furthermore, methods of follow-up vary considerably in different hospitals. For instance, many clinics base their follow-up results on letter writing, a most unsatisfactory method.

When we reached the conclusion that gastroenterostomy which we had used for many years was an unsatisfactory method, we decided that in order to obtain an actual appraisal of the situation, we would insist on personal interviews with the patient, supported whenever indicated by x-rays and gastric analysis. When I summarized the results (9) of our 5 to 10 years follow-up, I found that 34 per cent of the patients suffered from a gastrojejunal ulcer. 18 per cent were definitely proved when the gastrojejunal ulcer was found at reoperation. The remaining 16 per cent were based on clinical symptoms and x-ray findings.

In those days (about 20 years ago) few hospitals had effective follow-up systems. In fact, most surgeons relied on general impressions, not on accurate data. Our figures were, therefore, subjected to sharp criticism. It was stated that we did not know how to perform a gastroenterostomy properly. The fact that the vast majority of our patients were Jewish was given as the reason for the high incidence of gastrojejunal ulcers. However, during the succeeding 10 years, when other clinics introduced careful follow-up systems, the correctness of our figures was established. Some clinics showed an even higher incidence of gastrojejunal ulcer. The pendulum swung so strongly in favor of gastric resection for duodenal ulcer, that gastroenterostomy is now an operation of expediency, not one of choice.

After we had published our findings with respect to the incidence of gastrojejunal ulcer following gastroenterostomy, we began to compare the postoperative gastric acidity following gastroenterostomy with that following gastric resection. The findings were most impressive. Whereas among 62 cases of gastroenterostomy we (10) had an incidence of 3 per cent anacidity, there was an incidence of 66 per cent anacidity among 49 gastric resections (11). These figures were obtained with the Ewald test-meal, before the more accurate Rehfuss test-meal was introduced. However, the marked difference between 3 per cent and 66 per cent is of definite significance. The great value of gastric resection in the reduction of hyperacidity was evident in 8 patients whose histories I published from Dr. A. A. Berg's service (10). These patients had free hydrochloric acid varying from 20 to 68 following gastroenterostomy. When later re-examined after a secondary gastric resection for gastrojejunal or persistent duodenal ulcer, they all showed complete absence of free hydrochloric acid—truly an *experimentum in vivo*.

When we published our figures of 34 per cent of gastrojejunal ulcers following gastroenterostomy, we were told that after sufficient time had elapsed, we would undoubtedly observe the same percentage of gastrojejunal ulcers following gastric resection, if the same careful follow-up methods were used. This question can now be answered definitely in the negative. Mage has reviewed the material of the gastroenterological surgical group at Mount Sinai Hospital between 1923 and 1940. He studied 502 cases of gastric resection for duodenal ulcer and reports 2.5 per cent of gastrojejunal ulcers found at reoperation and another 5.5 per cent based on clinical evidence only. Thus the figures of 18 per cent (found at operation) and 34 per cent (diagnosed either by operation or clinically) of gastrojejunal ulcer after gastroenterostomy can be compared with those of 2.5 per cent and 8 per cent, respectively, following gastric resection. It seems that these comparative figures tell the whole story and indicate clearly the superior value of gastric resection.

Mage has included among the 40 gastrojejunal ulcers, 7 which had severe painless gross hemorrhage with negative x-ray findings. It is doubtful whether these cases should be included among the group of recurrent ulceration. I mention this group only in order to

show that Mage's figure of 8 per cent of gastrojejunal ulcers following gastric resection for duodenal ulcer including as it does some doubtful cases can be considered as definite and conclusive evidence of the marked reduction (34 per cent to 8 per cent) in the number of gastrojejunal ulcers as a sequela of gastric resection as compared with gastroenterostomy.

In a previous paragraph, I discussed the abuse of the term: "subtotal gastrectomy." I have pointed out how misleading the indiscriminate use of this classification is and how easily it leads to misinterpretation and misinformation. I would like to say here a few words about another abuse which has found its way in recent years into the description of operations, namely the term: "healed ulcer." Every surgeon, even the most experienced, knows the difficulties of exact palpatory findings. The surgeon may feel sure that he is dealing with a small duodenal ulcer, whereas the specimen fails to show any sign of an ulcer. When these cases are described as "healed ulcers" instead of as "showing no sign of ulcer," a proper statistical evaluation of the material becomes impossible. "Healed ulcers" never heal completely without leaving some sign of scar formation or remnants indicating the previous presence of an active ulcer, which can be demonstrated by the pathologist either macroscopically or under the microscope. When the pathologist reports completely normal findings, the surgeon has no right to speak of a "healed ulcer."

In recent years a number of authors seem to have rediscovered the antecolic method of connecting stomach and jejunum. This method represents the oldest form of gastroenterostomy. When Woelfler performed the first gastroenterostomy in 1881, he used the antecolic method without enteroanastomosis. Eleven years later, Jaboulay combined antecolic gastroenterostomy with enteroanastomosis in order to establish a better drainage of gastric contents.

Comparison of statistical material from different clinics is very difficult, because the basic facts vary so much. This holds true not only for follow-up statistics, but also for mortality statistics. One clinic will make frequent use of gastroenterostomy and reserve gastric resection for the easily resectable cases, whereas another clinic will use gastric resection in practically every instance. Frequent use of gastroenterostomy should not be encouraged, as a high percentage of patients thus treated are apt to suffer within a few years from gastrojejunal ulcer. It is very easy to keep the mortality for gastric resection for duodenal ulcer at a low level by the frequent use of gastroenterostomy. I have recently seen reports from two hospitals, one performing gastroenterostomies in 21 per cent of the cases and the other in even a higher percentage, 41 per cent. Such extensive employment of gastroenterostomy is inadvisable because some patients will later succumb following a subtotal gastrectomy for gastrojejunal ulcer, which operation has a higher inherent mortality than primary gastric resection for duodenal ulcer. The surgeons at the Lahey Clinic hardly ever use gastroenterostomy in the surgical treatment of duodenal ulcer. They have performed 235 consecutive gastric resections for gastric, duodenal, or gastrojejunal ulcers with a mortality of 2.7 per cent. In this series, 152 resections for duodenal ulcers were followed by 5 deaths, 3 per cent.

Wilson has reported 250 gastric resections for peptic ulcers (gastric, duodenal, gastrojejunal and those complicated with gross and massive hemorrhage) with a mortality of 2.8 per cent. In 7 additional cases palliative procedures were carried out. Drainage was used in very few exceptional cases.

One of the best statistics has been published by Koennecke, who performed between 1924 and 1931, 468 gastric resections for ulcer with a mortality of 1.5 per cent.

It is very evident that the mortality has decreased materially within the past 5 to 10 years. While formerly a mortality of 5 per cent seemed reasonable, evidently a mortality of 2 to 3 per cent is at present within reach of any surgical group trained for this special work. We should stop talking about the inherent high mortality of gastric resection for ulcer. The mortality of gastric resection should not be higher than that of gastroenterostomy, if the operation is done by experts; if it is higher, we should blame the surgical technique and not the method.

Another fallacious argument is the assumption that ulcers vary in different countries. When we tried to introduce gastric resection in this country, we were told that this major operation might be good for European ulcers, but that gastroenterostomy was an excellent operation for the much milder ulcers in this country. Time has proved the fallacy of this argument. In the same way, I believe that the operative material in our large cities throughout the country does not vary and offers the same operative risks.

SUMMARY

Gastric resection is at present the most popular method in the surgical treatment of duodenal ulcer. However, occasional attempts are made to put the clock back and to reintroduce gastroenterostomy. The term "partial gastrectomy" should be applied to the operation performed for duodenal ulcer. The difficulty of comparing statistics from different hospitals is discussed. We cannot classify a case as a "healed ulcer," unless the specimen shows evidence of a previous ulceration. The mortality following gastric resection for duodenal ulcer has been reduced in recent years. It is now as low as that of gastroenterostomy.

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# ACTIVE MOTION BY MEANS OF OCCUPATIONAL THERAPY IN THE TREATMENT OF FRACTURES

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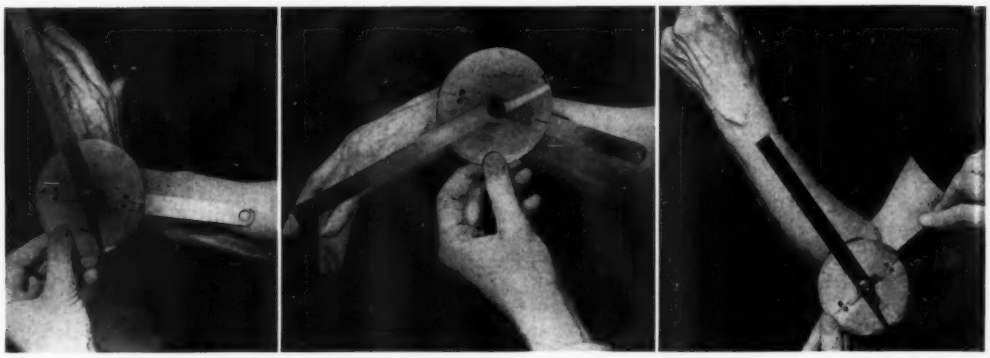
IF the standard textbooks dealing with the treatment of fractures are consulted there is usually an accurate description of the various methods used by the author for the treatment of a particular fracture, and at the end of the description in rather a slurring or brief paragraph, the author discusses the most important part of the treatment with such description as "active motion is started in the fourth week," or "physiotherapy is started at once." These terms do not convey much to the student or the practitioner as they have become meaningless without some description of the *modus operandi* of these procedures. The same reaction is true in reading or listening to papers on the subject of the treatment of fractures. Most of us will concede that the early return to function is at least as important as an accurate anatomical alignment. Boehler has certainly stressed early return to function by the use of the walking cast, but in reading his text it becomes obvious that he never forgets the principle of complete immobilization until firm union occurs. This principle must be closely adhered to under any and all circumstances, otherwise failure is sure to occur. The time element must not be dogmatically stated because all of us have seen fractures which in an average individual will unite firmly in, perhaps, 8 weeks, yet in some patients will take 12 weeks. Union must be actually determined by both clinical and roentgenological evidence, and when there is a doubt immobilization should be maintained until that doubt is gone.

What has happened to the advocates of passive motion? In the not so distant past, the so called "after treatment" consisted of active and passive motion, baking, and massage. In a short time passive motion was abandoned because the careful observer often saw actual damage and retardation of the sought for result. Passive motion actually did more damage to the joint and muscles than was produced by trauma at the time of the original injury. Now it can safely be said that at no time should passive motion be used in the treatment of fractures. The subject of baking and massage is very elaborate and there are still many clinics which use this form of physiotherapy exclusively for restoration of function. On careful questioning and observation I find that most men today believe that baking and massage are of practically no value as far as functional return is concerned and certainly that vigorous massage can produce deleterious results which definitely retard an early good end-result. The newer fads, of course, are diathermy and short wave therapy applied to the injured part. Again, on the basis of my observations, these modalities do not assist the patient to get function. At best they may cause the subsidence of pain while the treatment is being applied, but the effect is not lasting. On the other hand, if the part has been properly and adequately immobilized until firm union occurs, pain is not much of a factor; so these modalities, since they do no recognizable good, may be dispensed with.

Properly applied, active motion may bring about a quicker return to normal function than will any other method or combination of methods. To clarify our ideas, a few definitions are necessary.

Occupational therapy (3), or better still functional occupational therapy, implies physical activity prescribed and guided to bring about active motion in the joints under treatment; it is given in increasing doses as the patient shows improvement. This form of therapy provides a medium of carefully graded exercises or activities for joints stiffened by immobilization and atrophy of muscles and improves venous and lymphatic circulation in the extremities. Since these results are accomplished by active motion, the return to normal function is accelerated. The purpose



Figs. 1, 2, and 3. Arthrometer used to measure limitation of motion of wrist and elbow joint.

of the therapy is to arouse interest, courage, and confidence, and to re-establish capacity for industrial usefulness (2). It should be supervised by the surgeon and directed to the correction of a particular need.

At Bellevue Hospital on the Fourth Surgical Division, we have been using this form of treatment in fractures since 1927. This method, on our division, is used practically to the exclusion of all other methods. More recently we have not allowed the time before discharge of the patient from the hospital to go to waste. While the patient is still confined to bed, the occupational therapist comes to the ward and instructs the patient by various means of activities to move all joints and muscles of the extremity not actually encased in plaster or otherwise immobilized. When the patient is convalescent and about on crutches, he is sent to the occupational therapy in-patient workshop for continuation and acceleration of this treatment. After discharge from the hospital the patient returns to the out patient department workshop three times a week and in the interim returns to the fracture clinic at intervals suggested by the surgeon. The occupational therapist also attends this clinic (with the patient's occupational therapy progress and joint measurement charts) to discuss with the surgeon and the patient the improvement noted and the increase of dosage indicated. In this way a complete progress record is kept.

The matter of records is very important and they must be kept accurately or they lose their value to both the surgeon and the patient (5). An arthrometer is used by the occupational therapist to measure the various joints. The instrument (Figs. 1, 2, 3) is simple to handle and easy to read. (A simple one can be made at home with two brass protractors and two sturdy brass or aluminum bars.) Each week the limitations of the joint motion are measured and recorded in graph form on the reverse side of the patient's progress chart. If the patient complains of joint pain and the measurement chart shows no progress, or perhaps retardation, he is immediately referred back to the fracture clinic for further examination by the surgeon to discover what complicating factor is responsible for his lack of progress. When this trouble is corrected the therapy can again be resumed.

The specific application of activities as exercises is carefully worked out for all joints of the extremities and other supplementary activities, such as dish washing, sweeping, etc. may be used or omitted as seems advisable in individual cases. All activities to be adaptable for exercises should have one or more of the following characteristics (6):

1. Repetition of the motion desired.
2. Gradation of the weights (that is, tools or equipment) or force (which could be the thickness or hardness of the wood or material) opposed to muscle action in proportion to its increase in strength.
3. The alternate contraction and relaxation of muscles.
4. Graded range of motion through which a joint is taken in performing any action.

Figs. 4, left, and 5, center. Card board weaving device to promote flexion (Fig. 4) and extension of fingers (Fig. 5). Fig. 6, right. Winding material into ball. Ball is held in uninjured hand while injured hand holds ball, promoting extension and flexion of fingers and adduction and abduction of wrist.

The treatment of fractures, the aim of the occupational therapy, is to assist in the restoration of joint motion and muscle strength and to induce voluntary motion by diversion of the mind (4). The frequency of treatment depends on the individual patient, but usually it is given every other day by a trained occupational therapist, and on intervening days home exercises are given to continue the active motion. Treatment is never carried beyond the fatigue point. In the beginning the activity period is short with rest periods between but, as progress is made, the activity periods are lengthened and the rest periods shortened. In fractures about the wrist, such as a Colles fracture, after the period of immobilization is over and the patient is examined by the surgeon in the fracture clinic, it is customary immediately to refer him to the occupational therapy workshop for active motion. Usually he lacks grasp of fingers, flexion and extension of wrist, and pronation and supination of the forearm. The procedure of the occupational therapy treatment is carried out, depending on the individual patient and his outstanding limitations and disabilities, approximately as follows:

*Fingers: principal disability—grasp*

Simple card board weaving:

1. Patient seated sideways, resting injured forearm on table (this, to prevent added strain on arm). Hand pronated on loom, patient actively attempts to flex fingers by pulling down on weaving threads (Fig. 4).

2. Loom reversed, weaving threads are pushed into place by patient, actively attempting to extend fingers (Fig. 5).

3. Adduction and abduction of thumb may be obtained by patient pushing threads into place with thumb.

Looping weaving material:

1. Cloth cut into suitable width strips for weaving is slit at both ends. Patient (arm still resting on the table) is directed to loop each strip through the slits and thus make a continuous cord. Definite flexion of the fingers is required to do this. At first, assistance may be given with the uninjured hand, gradually doing more and more with the injured hand (Fig. 3).

Winding weaving materials:

1. The aforementioned yards of cord are wound into balls. The size of the ball used depends on the limitation of the fingers (Fig. 6).

2. Winding is done with the uninjured hand and the ball is held in the injured hand (arm resting on the table). Fingers are extended and flexed and thumb adducted and abducted individually to allow strand to encircle ball.

Note: Activities are given for a limited number of times (say 5, with rest periods). As soon as the patient can perform a given activity with comparative ease, he is advanced to a more difficult one.

*Wrist: principal disabilities—flexion, extension, pronation and supination*

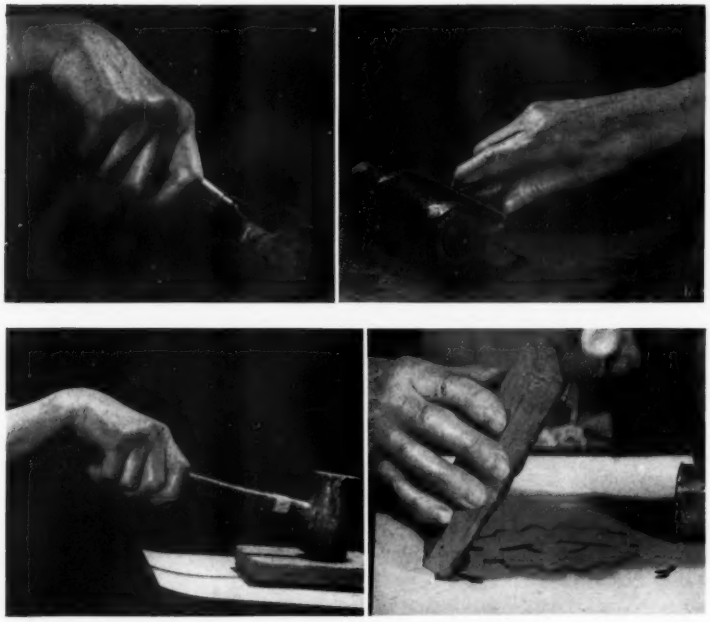
Block printing:

1. Flexion of fingers—grasping brayer (roller) (Figs. 7, 8).

2. Patient passes brayer back and forth over block printing ink (preferably water soluble), hand in pronation, the backward motion encourages flexion of wrist, the forward motion extension of wrist.

Note: Elbow is kept as quiet as possible, but some compensation must be allowed with early fracture cases or patient might exert too much force against injured area which could result in damage to the bone or soft tissue. No attempt is ever made forcibly to hold the elbow forearm quiet.

3. The inked brayer is then lifted to the block (the size of block depending on patient's grasp) and the brayer rolled back and forth as described.



Figs. 7, 8, above, 9, and 10, below. Block printing, to promote flexion of fingers, pronation of hand, flexion and extension of wrist. Hammer tapping printing block promotes pronation of hand, hyperextension of wrist as well as flexion of wrist. Figure 10 shows print made.

4. Block is then raised on edge with uninjured hand (to prevent patient from smearing paint over himself) and lifted by the edges with extended fingers of injured hand, and placed on paper to be printed. Slight supination is afforded in this process.

5. The block is tapped with a light weight hammer or mallet (usually 2 oz. to begin with) (Fig. 9). Hand pronated, the wrist is hyperextended as far as comfortable *without forcing*, and the patient allows the weight of the hammer to flex the wrist when striking the block. No force is required or allowed in this procedure. The motion must all originate in the wrist itself or it is of no value. If the first print on the paper is not too distinct, it is of no importance, as each additional print will improve. Frequently the first print is kept to show the patient later, and let him compare his improvement (Fig. 10).

6. Lifting the block, with the injured hand, from the paper and replacing it right side up on the table provide considerable supination.

7. Pronation and supination may also be obtained by use of hammer in tapping block for print. Holding the forearm in mid-position and tapping block first by supinating arm as far as possible without forcing, and then pronating arm as far as possible, without forcing (Fig. 11).

8. Adduction and abduction of wrist can be obtained by holding forearm in mid-position, first adducting and then abducting wrist, when tapping block.

9. Gradation is obtained by: gradually increasing the weight of the hammers, 2, 5, 7 ounces; increasing or decreasing the size of the block, according to limitations of flexion or extension; gradually increasing the length of work periods.

Wood filing (circular stool top, breadboard, tray, etc.):

1. Wood placed on end in vise.

2. File held at both ends, with both hands (grasp), passed back and forth over circular surface. Extension of wrist is obtained as file moves forward, flexion of wrist as file moves back (Figs. 11, 12).

3. This procedure may also be used with dowel sanding block.

Sawing (use of small hand coping saw):

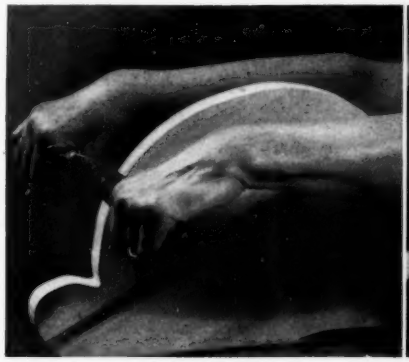
1. Thin wood used at first (¼ in.); straight lines to teach patient "feel" of the wood, so that he will not be discouraged.

2. Holding saw handle (grasp).

3. Hand in pronation, passing saw back and forth over wood, backward motion gives flexion of wrist, forward motion gives extension of wrist (Figs. 13, 14).

4. Supination may be obtained by turning saw upside down, and sawing *up*.

5. Gradation accomplished by increasing thickness and weight of wood.



Figs. 11, left and 12. Wood filing to promote extension as well as flexion of wrist.

Figs. 13, left and 14. Coping saw to promote flexion and extension of wrist as well as flexion of fingers in grasping saw handle.

Screwing:

1. Pronation and supination may be obtained by use of the screwdriver in the construction of a project. (Care being taken not to use shoulder rotators.)

Table I gives statistics showing the final results with various types of fractures (over a period of 5 years) in the out patient department workshop at Bellevue Hospital. Only fracture cases have been listed. The shop handles, aside from this type of trauma, other cases such as burns, severed tendons, etc.

It has been the policy of the occupational therapy department to try to have the patient make three projects during his total treatment period. One of these he keeps for himself, the other two are sold by the department. The proceeds of these sales form a revolving fund which in turn purchases new materials, thus helping to defray the expenses naturally encountered in such an undertaking.

## CONCLUSIONS

1. Occupational functional therapy is a distinct help in the treatment of injuries to the extremities. It rehabilitates the patient in the shortest possible time.

2. By means of the arthrometer and proper charting, progress becomes an accurate measurement rather than a guess.

3. Treatment is continuous and is carried out at the occupational clinic and at home.

4. Return to normal function is shortened in fractures of the extremities.

5. An accurate chart of all joint ranges is appended.

## JOINT RANGES

No joint motion goes beyond 245 degrees. When measuring joint see this circle. Center of circle represents the joint. Above this is the immovable bone. This bone goes from center of circle to 0. Movable bone—from center of circle, down.

## TABLE I.—SUMMARIES

### WRIST FRACTURES—246 Cases*

| Recovery classification | No. of patients | Period of time spent in O.T. | Average total treatments | Those having less than 5 treatments | Patients who returned to work |
|---|---|---|---|---|---|
| 100% | 41 | 2 mos. 5 days | 19 | 4 | 13 |
| Improved | 101 | 2 mos. 5 days | 17 | 12 | 12 |
| Slightly improved | 31 | 2 mos. 4 days | 18 | 11 | 1 |
| Unimproved | 10 | 1 mo. 3 wks. 3 days | 13 | 4 | 1 |
| Did not return | 44 | | | | |
| Not measured | 19 | | | | |
| Total surveyed | 246 | 2 mos. 2 wks. 3 days | 13 | 31 | 27 |

### ELBOW FRACTURES—109 Cases†

| | | | | | |
|---|---|---|---|---|---|
| 100% | 13 | 2 mos. 6 days | 36 | 1 | 6 |
| Improved | 38 | 1 mo. 2 wks. 2 days | 16 | 9 | 3 |
| Slightly improved | 16 | 1 mo. 2 wks. 4 days | 12 | 6 | 0 |
| Unimproved | 11 | 2 mos. 2 weeks | 24 | 4 | 0 |
| Did not return | 26 | | | | |
| Not measured | 5 | | | | |
| Total surveyed | 109 | 1 mo. 2 wks. 4 days | 14 | 20 | 9 |

### ANKLE FRACTURES—143 Cases

| | | | | | |
|---|---|---|---|---|---|
| 100% | 25 | 3 mos. 5 days | 23 | 1 | 19 |
| Improved | 69 | 2 mos. 2 wks. 6 days | 16 | 8 | 13 |
| Slightly improved | 5 | 2 mos. 2 wks. 6 days | 10 | 1 | 0 |
| Unimproved | 0 | | | | |
| Did not return | 35 | | | | |
| Not measured | 9 | | | | |
| Total surveyed | 143 | 1 mo. 3 wks. 2 days | 12 | 10 | 32 |

### KNEE FRACTURES—86 Cases

| | | | | | |
|---|---|---|---|---|---|
| 100% | 9 | 3 ms. 2 wks. 5 days | 36 | 0 | 7 |
| Improved | 45 | 2 mos. 3 wks. 1 day | 21 | 0 | 17 |
| Slightly improved | 7 | 1 month 4 days | 7 | 2 | 0 |
| Unimproved | 7 | 1 month 3 days | 10 | 2 | 0 |
| Did not return | 18 | | | | |
| Not measured | 0 | | | | |
| Total surveyed | 86 | 2 months 1 day | 16 | 4 | 24 |

O. T. Occupational therapy.
*1 compensation; 1 reversed fracture; 1 saved operation.
†1 open reduction; 1 compensation case; 1 psychopathic case; 1 refused to cooperate.

*100%.* Patients having both normal flexion and extension.
*Improved.* Patients having normal motion in either flexion or extension but lacking 5 to 30 degrees in either direction; and patients lacking 5 to 30 degrees flexion or extension or both.
*Slightly improved.* Patients having normal motion in either flexion or extension but lacking 35 to 50 degrees in either direction; and patients lacking 35 to 50 degrees' flexion or extension or both.
*Unimproved.* Patients having normal motion in either flexion or extension but lacking 55 to 75 degrees in either direction; and patients lacking 55 to 75 degrees' flexion or extension or both.
*Did not return.* Patients who reported for only 1 or 2 treatments; most of whom no follow-up could be made.
*Not measured.* Patients who reported for only 1 or 2 treatments and whom we were unable to measure at periods they reported.

*Elbow joint.* Moves from 180 to 40 degrees. Normal range: flexes to 40 degrees; extends to 180 degrees; range of motion—140 degrees.

*Fingers.* First joint—metacarpophalangeal joint: flexes to 90 degrees; extends to 180 degrees; range—90 degrees. Second joint: flexes to 70 degrees; extends to 180 degrees; range—110 degrees. End joint (distal phalanx): flexes to 140 degrees; extends to 180 degrees; range—40 degrees.

*Thumb.* Only 2 joints. Carpal metacarpal joint (in the hand): flexes to 120 degrees; extends to 180 degrees; range—60 degrees. Metacarpal phalangeal: flexes to 160 degrees; extends to 180 degrees; Range —20 degrees. Interphalangeal joint: flexes to 90 degrees; extends to 180 degrees; range—90 degrees.

*Wrist joint.* Flexes to 100 degrees; hyperextends to 245 degrees; range—145 degrees.

*Shoulder joint.* Flexes to 20 degrees; hyperextends to 220 degrees; range—200 degrees.

*Ankle joint.* Measured from 180 degrees' extension toward 0, decreasing the angle; angle 115 to 170 degrees.

*Knee joint.* Flexes to 45 degrees; extends to 180 degrees; range—135 degrees.

*Hip joint.* Flexes to 60 degrees; hyperextends to 220 degrees; range—160 degrees.

*Degrees of abduction and adduction.*

*Wrist.* Abducts to 155 degrees; adducts to 215 degrees; range—60 degrees.

*Shoulder* abducts to 20 degrees; adducts to 180 degrees; range—160 degrees.

*Hip* abducts to 115 degrees; adducts to 180 degrees; range—65 degrees.

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# SURGICAL TREATMENT OF URINARY OBSTRUCTION IN ARMY GENERAL HOSPITALS

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IN civilian practice urinary obstruction implies primarily diseases of the prostate. In the Army urinary obstruction presents a generous variety of lesions involving the entire urinary tract, including an occasional obstructive prostate in the senior age group.

The obstructive lesions most frequently encountered in the Service are: (1) contractures of the bladder neck, (2) ureteropelvic constrictions with or without aberrant renal vessels, (3) urethral strictures and small meatuses. These obstructions are seen somewhat earlier in the Army than in civilian patients because the advanced cases are screened out by induction urine examinations. At least 90 per cent of these obstructions probably existed prior to induction. Service-connected aggravation may result at any time by interposing infection or calculi or both.

The purpose of this paper is to point out that, after careful evaluation, it is possible to correct many of these obstructions and restore these patients to full military duty.

## CONTRACTURES OF THE VESICAL NECK

Narrowing of the bladder outlet due to fibrosis or muscular hypertrophy is a common lesion seen in an Army general hospital. Many of these obstructions manifest themselves during early childhood and adolescence. They are slowly progressive. Contractures may be classified as mild, moderate, and severe. They can be separated clinically into 3 groups, depending upon the degree of progression. Group I: Stage of vesical irritation, manifested by intermittent frequency, urgency, or nocturia with a clear urine. Group II: Stage of residual urine and trabeculated bladder. During this period there is a noticeable narrowing of the urinary stream with difficulty in voiding. Sexual symptoms as premature ejaculations, desire to masturbate, or sexual neurasthenia may also plague these patients. During acute exacerbations urinary symptoms become more severe, often associated with terminal dribbling, dysuria, suprapubic and perineal discomfort, backache, renal colic or hematuria. Group III: Stage of acute retention of urine with inability to void

Pathologically these contractures may be divided into superficial and deep. In the former there is a superficial bladder neck sclerosis without adnexal involvement. In this superficial group we also find the pure bladder neck muscular hypertrophy producing urinary obstruction (Fig. 1). In the latter group the bladder neck fibroses result from long standing associated chronic posterior urethritis and prostatovesiculitis. A well established fibrosis will result either in shortening of the retromontane urethra or the trigone, of which urethral shortening is more common in the ratio of 5 to 1. Bladder deformities, diverticula, pyelonephritis, and infected hydronephroses are associated pathology noted in advanced infected cases. Multiple diverticula are more apt to develop in the presence of inflammatory bladder neck obstructions.

The diagnoses are made from the history and physical findings. The latter may be entirely negative. Cystourethrograms reveal vesical neck constriction and the associated bladder pathology. Rectal palpation of the bladder neck over an instrument in the deep urethra will reveal the degree of posterior commissural thickening. Cystoscopy shows the deep urethral, vesical neck, trigonal, and bladder wall changes. Elevation of the posterior vesical lip with deformity of the vesical outlet is readily observed.

The treatment of the early cases should be conservative. Bedrest, sedatives, and heat

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Read before the Utah State Medical Association, Salt Lake City, Utah, August 26, 1944.

Fig. 1. Med. Officer, age 42 years. Smooth muscle hypertrophy of vesical outlet resulting in 900 cubic centimeters of infected residual urine and bladder atony. Six grams of tissue removed successfully transurethrally. Duty.

Fig. 2. Age 38 years. Marked fibrosis of vesical neck and prostatic calculi. Diffuse Staphylococcus aureus urinary tract infection. Sulfonamides and penicillin resistant. Improved following transurethral resection of 20 grams of tissue.

will improve the symptoms. Urinary antiseptics are rarely helpful. Bladder neck dilatation may temporarily relieve the symptoms and suggest early contracture. When symptoms of vesical irritability are temporarily relieved following cystoscopic examination, a contracture should be suspected. After these patients have reached the stage of residual urine or acute retention, transurethral resection is indicated. Surgery in these cases may accomplish more than years of prostatic massage and local treatment. It is necessary to remove 5 to 20 grams (Fig. 2) of obstructive tissue from the bladder neck, posterior urethra and prostate for satisfactory postoperative bladder drainage. Carefully selected patients operated upon can be rehabilitated and returned to full duty after 8 to 12 weeks' hospitalization. Neurogenic bladders associated with a mild vesical neck obstruction lend themselves equally well to bladder neck resection and improved bladder function. A mild bladder neck obstruction becomes a major obstruction in the presence of a weakened detrusor muscle.

### HYDRONEPHROSIS

The most common lesions of the upper ureter interfering with free renal drainage are: ureteropelvic strictures, aberrant lower pole renal vessels, periureteral adhesions, and kinks. The presence of a calculus or calculi will further impede renal drainage. Occasionally, postoperative peripelvic and periurethral fibroses will develop and cause obstruction. Ureteral strictures and aberrant vessels are noted clinically more frequently in the second decade. They are congenital and are usually asymptomatic until infection or calculi or both have developed. They may be unilateral or bilateral. In degree they are mild, moderate, or severe. After infections develop these kidneys are resistant to conservative treatments including the sulfonamides and penicillin. These therapeutic agents may temporarily clear the urine, but relapses are the rule. Intravenous and retrograde pyelograms, bacterial and renal function studies will usually suffice for accurate diagnoses.

The treatment of these lesions is primarily surgical. In a few instances temporary improvement may result following ureteral dilatation. The surgical correction consists of pyeloplasties on the ureteropelvic junction, resection of aberrant vessels, resection of large pelves, and nephropexies. We favor the Heineke-Mikulicz and the Foley Y plastic procedures. The preferred plastic procedure in most cases is best determined at the operating table. The best functional results are obtained when surgical correction is undertaken prior to infection. Preoperative and post-

operative sulfonamides or penicillin or both will greatly enhance satisfactory surgical results. Infected pyeloplasties should be splinted with a small soft rubber catheter or a common duct T tube as recommended by Deming. Uninfected pyeloplasties followed by renal fixation do not need ureteral splinting. In fact, ureteral splinting may invite postoperative infection. When the pelvis is large, partial resection will aid postoperative renal drainage (Fig. 3). In advanced cases, temporary pyelotomy or nephrostomy drainage tubes should be utilized.

Aberrant renal vessels may be treated by resection or reimplantation of the ureter. When only a small amount of renal parenchyma is involved, removal of the vessel or vessels is the operation of choice. The extent of the aberrant arterial blood supply can be quickly determined by simple compression of the vessel. Coexisting ureteropelvic narrowing can be easily overlooked at the time of operation. In some instances better results could be obtained if a pyeloplasty were done in addition to removal of the vessels (Fig. 4). All patients operated upon should have follow-up postoperative excretory pyelographic studies so that the final result may be evaluated.

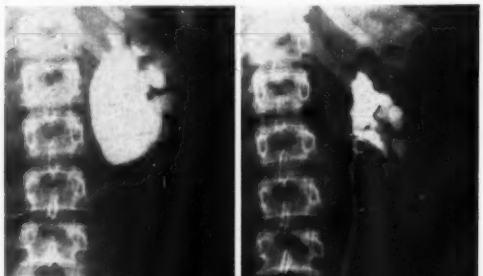

Fig. 3. Age 21 years. Stricture of ureteropelvic junction, hydronephrosis, calculi (2). Pyeloplasty and pelvic resection. Postoperative pyelograms revealed satisfactory result. Duty.

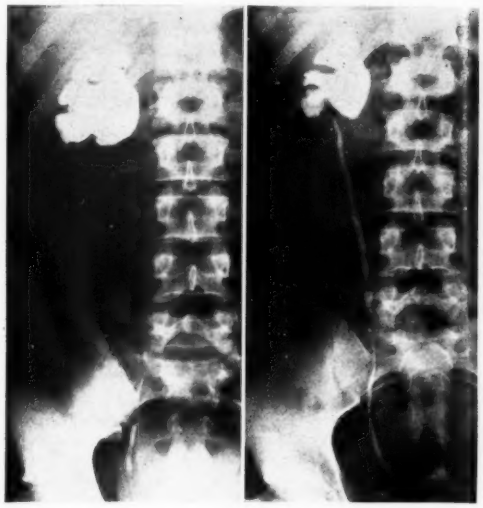

Fig. 4. Age 20 years. Aberrant artery and vein, ureteropelvic kink and adhesions, and infected hydronephrosis. Resection of aberrant vessels and release of adhesions. Improvement, questionable mild postoperative pelvic retention. Duty.

### URETHRAL STRICTURES

Urethral strictures, small and wide caliber, were noted in 12 per cent of our admissions. The wide caliber (larger than 20 F.) except for producing a slight morning drop, a mild pyuria and shreds in the first glass of urine may be asymptomatic. They frequently respond promptly to one or two urethral dilatations. Asymptomatic large caliber fibrous strictures should be left alone. The small caliber multiple anterior urethral strictures present a complex military therapy problem. They occur more often in a soldier who has had repeated gonorrheal infections and recurrent urethral discharges. Examination reveals a purulent discharge, pyuria, adnexitis, with or without chronic epididymitis. When severe strictures are complicated with acute gonorrhea and/or trichomonas genitalis the latter are usually resistant to sulfonamides and penicillin. Improvement in urethral drainage is the keynote in their management. This may be accomplished by progressive urethral dilatation or internal urethrotomy. Symptomatic urethral strictures should be treated by progressive dilatation. Fibrous and resilient

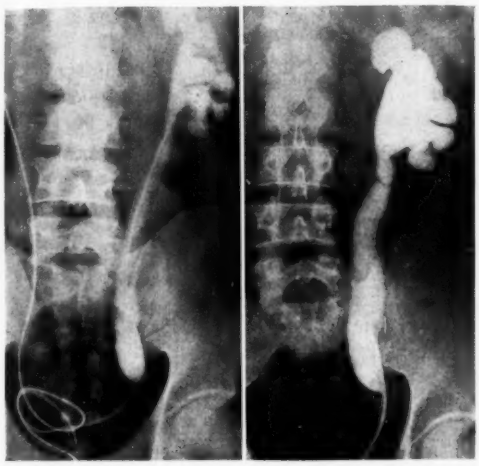

Fig. 5. Age 37 years. Neuromuscular deficiency and left renal calculi. Exploratory and ureteral mobilization was followed by increased ureterectasis due to inadequate intrinsic innervation. Certificate of Disability Discharge.

strictures respond poorly to dilatation. These resistant strictures should be cut. In our hands, electrourethrotomy gives superior results. Severe urethral strictures necessitate long hospitalization, observation, and treatment. With notable exceptions, the severe anatomical and physical disabilities preclude probable military rehabilitation. Before treatment is undertaken, separation from the service should be considered particularly in the maladjusted individual. Service-connected urethral injuries and strictures, however, should receive every consideration of current available therapeutic measures.

Small external urinary meatuses are usually congenital and have no clinical significance except in the presence of urethritis. Improved urethral drainage by simple meatotomy will aid materially in clearing some patients with resistant venereal or nonvenereal urethritis.

CASE 1. J. E. B., aged 21 years, acquired gonorrhea overseas 2 months before. He received 125 grams of oral sulfonamides and 4 courses of penicillin, total 700,000 units, while overseas, without benefit. Smear and culture on admission June 17, 1944, were positive for gonococci. Examination revealed a redundant prepuce, small meatus, purulent discharge, and hazy urine. Circumcision and meatotomy were carried out 3 days later. Subsequent smears and cultures remained negative. Provocatives failed to reactivate the disease. Considered clinically well July 13, 1944.

### INTRINSIC URETERAL STRICTURES

Intravenous pyelography, more than any other diagnostic procedure, has helped to suspect and identify ureteral strictures. The incidence is approximately 2 per cent in large series of urologic examinations. Ureteral strictures are relatively asymptomatic until sufficient obstruction develops to invite infection. Suspected ureteral strictures can be verified by ureteral calibration. However, our interpretation of ureteral blockage to a catheter can be very misleading. Nonopaque calculi, mucosal pockets, lateral angulation, and spasm are frequently erroneously diagnosed as strictures. Neuromuscular deficiencies (Fig. 5) and ureteral dilatation resulting from chronic infection frequently suggest stricture on pyelography (Fig. 6). In these cases ureteral calibration will usually rule out intrinsic strictures. The treatment of ureteral strictures is progressive dilatation and clearing of the coexisting infection. Extrinsic ure-

Fig. 6. Age 24 years. Pyelonephritis, bilateral, severe, Staphylococcus aureus, temporarily improved with penicillin. Bilateral ureterectasis due to chronic infection. No. 9 F. catheters passed easily. Prognosis poor. Certificate of Disability Discharge.

teral lesions causing urinary obstruction are omitted from this discussion.

## OBSERVATIONS

The problem of urinary obstruction in the Army presents the same overall picture as seen in civilian practice. When dealing with large numbers of young men, congenital obstructive lesions predominate over the acquired obstructive lesions of senescence. Many obstructive lesions in the Army are noted before serious complications have had the opportunity to develop. Army Medical Officers, following the slightest suspicion of obstructive pathology, carry out urologic examinations sufficiently early to turn up many of these serious developing lesions. The earlier these cases are accurately diagnosed, the more amenable they are to correction. Surgical reconstruction of the pelvic or bladder outlet obviously is simpler in early uninfected cases than in late neglected ones.

Surgeons of experience are alert to the tremendous opportunities in conservative renal and bladder surgery. Aside from some anatomical landmarks, it does not require an unusual amount of surgical skill to remove a kidney. On the other hand, conservative renal surgery is not unusually difficult either. It does require, however, a surgeon of sufficient experience who is anxious to "restore" as well as "remove." In addition, carefully trained and organized personnel and equipment are essential to achieve the best results. The activation of Army Surgical Centers during this emergency by the Surgeon General has aided immeasurably in the rehabilitation of patients requiring highly specialized treatments.

In the Army, then, there is ample opportunity to apply principles of recognized urologic conservative measures. These applied procedures will not only rehabilitate these patients during this emergency, but will in a great measure add to their health and happiness following their discharge from the service.

It has been charged that the Army neglects to take care of some of these EPTI (existed prior to induction) lesions. This charge may well be true. A surgeon in the Army, however, must evaluate the entire individual, his length of service, as well as the specific lesion in question. Surgery performed upon an unhabilitable soldier may facilitate later pension claims to our government from $30,000 to $50,000 each.

## CONCLUSIONS

1. Urinary obstruction in the Army is a common lesion involving most frequently the upper ureter, bladder neck, and urethra.

2. The majority of these lesions existed prior to induction.

3. The prostatic diseases of senescence are uncommon.

4. Ample opportunity exists in the Army to correct these congenital obstructive lesions early with minimum morbidity and mortality.

5. In maladjusted and inadequate Service patients, surgery for lesions, which existed prior to induction unless emergent, is usually contraindicated.

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# ANATOMICAL AND SURGICAL RESTUDY OF DENONVILLIERS' FASCIA

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THE tissue which lies anterior to the rectum and posterior to the prostate, seminal vesicles, and bladder has become known as the fascia of Denonvilliers (Fig. 1) from his description of this tissue in 1836 and 1837. Since the present interpretation of the position and structure of this tissue appears to be uncertain, Denonvilliers' description of this fascia (Fig. 2) and its translation are given as the first step in the approach to this restudy.

Behind the prostate, between the seminal vesicles and the rectum, there is a distinct membranous layer, which I call prostatoperitoneal. This is its position: from the two sides it fuses with the compact cellular tissue which surrounds the venous plexus at the base of the bladder; on the anterior side it loses itself in the most distant side of the prostate; on the posterior side it adheres to that part of the peritoneum which descends between the bladder and the rectum. This adherence, very marked, as close as if it were fused with the tissue, explains the constancy of the recto-vesical cul-de-sac of the peritoneum; the half-moon form of this cul-de-sac which lies at the posterior border of the aponeurosis that always describes a curve with convexity in front, or which represents (is in the form of) a "V" jutting in anteriorly at an angle. The inferior surface which touches the rectum barely adheres to it by a very loose cellular tissue; from the upper surface, however, some thick cellular projections arise which surround the seminal vesicles. The texture of this membranous layer resembles that of the dartos; it appears to be formed principally by fibers which separate while radiating from the posterior part, and those occupying the median line are the most prominent; in vigorous subjects some evident muscular fibers exist, but only on the sides. Whatever is the additional arrangement of this membranous layer, it is very resistant, and forms a completely closed space at the base of the bladder, in which the seminal vesicles and a part of the ureters and vasa deferentia are enclosed; these enter into the cavity by means of very thick cellular tissue which forms their lateral sides.

Subsequent to Denonvilliers' description of the prostatoperitoneal membrane, many conflicting reports have been published as to its embryological origin, gross anatomical structure, and surgical importance. Two diametrically opposed embryological theories have been advanced. Cunéo and Veau (1899), Smith (1908), and others claimed that all of this tissue is derived from a cul-de-sac of peritoneum which extends into the pelvis of the fetus and young individual. On the contrary Wesson (1922 and 1923) maintained that Denonvilliers' fascia is derived from the mesenchyme around the rectum, prostate, seminal vesicles and bladder and that the cul-de-sac of pelvic peritoneum, between these structures, reverted to undifferentiated embryonic tissue or persisted for a short time as a pseudoraphe; or wherever apposition had not been complete, a cyst may form.

The gross anatomical structure of the prostatoperitoneal membrane has been described as consisting of one or more layers, depending on the interpretation of the original description of this tissue and the cleavage planes made in dissecting this region. Descriptions have been given of: (1) a layer of areolar tissue surrounding the rectum which might contain a considerable amount of fat in some individuals; (2) a resistant, glistening layer forming the posterior covering of the seminal vesicles and prostate; (3) a continuation of this resistant layer over the anterior surface of the seminal vesicles (between the bladder and seminal vesicles); (4) a "V"-shaped fibrous membrane, extending from the urogenital diaphragm to the peritoneum, which is adjacent to or fused with the posterior layer of the prostate and seminal vesicles; and (5) a similar band attached to the connective tissue on the superior border of the seminal vesicles (Denonvilliers, 1836 and 1837; Smith, 1908; Wesson, 1922 and 1923; Young, 1926; Hinman, 1935; Belt and associates, 1939; Lowsley and associates, 1942; and others).

Clinically, Denonvilliers' fascia is not only an important anatomic landmark in the surgical approach to the prostate and seminal vesicles but it is also considered an effective barrier in limiting the spread of pus, extravasated urine, and malignant tumor of the prostate,

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Fig. 1. Charles-Pierre D. Denonvilliers, 1808–1872. Portrait from: Corlieu (A.). Centenaire Fac. de méd. de Paris. Paris, 1896, in the Army Medical Library, Washington, D. C.

— 23 —

En arrière de la prostate, entre les vésicules séminales et le rectum, existe une couche membraneuse bien distincte, que j'appelle *prostato-péritonéale*. Voici quelle est sa disposition : Des deux côtés elle se confond avec le tissu cellulaire serré qui entoure les plexus veineux du bas-fond de la vessie; par son bord antérieur, elle se perd sur l'extrémité la plus reculée de la prostate; par son bord postérieur elle adhère à cette portion du péritoine qui descend entre la vessie et le rectum. Cette adhérence, des plus marqués, aussi intime que s'il y avait confusion de tissu, explique la constance du cul-de-sac recto-vésical du péritoine; la forme en demi-lune de ce cul-de-sac se lie à la disposition du bord postérieur de l'aponévrose, lequel décrit toujours une courbe à convexité antérieure, ou qui représente un V à angle saillant en avant. La face inférieure qui touche au rectum lui adhère à peine par un tissu cellulaire très-lâche; de la face supérieure s'élèvent, au contraire, des prolongements celluleux assez denses qui enveloppent les vésicules séminales. La texture de cette couche membraneuse se rapproche de celle du dartos; elle paraît principalement formée par des fibriles qui partent en rayonnant de la partie postérieure, et dont celles qui occupent la ligne médiane sont les plus prononcées; chez les sujets vigoureux des fibres musculaires manifestes existent, mais seulement sur les côtés. Quelle que soit au reste l'organisation de ce plan membraneux, il est très-résistant, et forme avec le bas-fond de la vessie une espèce de loge exactement close de toutes parts, dans laquelle se trouvent renfermées les vésicules séminales et une partie des uretères et du canal déférent; ceux-ci s'introduisent dans cette cavité au milieu du tissu cellulaire très-dense qui en forme les parois latérales.

Fig. 2. Photograph of page 23 from Denonvilliers' *Thesis*, 1837, "Propositions et Observations d'Anatomie, de Physiologie et de Pathologie" giving his description of the tissue known as Denonvilliers' fascia.

seminal vesicles, and rectum. Therefore, the following study was undertaken as an attempt to clarify the embryological origin and anatomical structure of Denonvilliers' fascia and to ascertain the parts of this fascia encountered in the perineal approach to the prostate.

## MATERIAL AND METHODS

Sections from 11 human embryos (6 mm. C.R.L.[1] to full term) were studied for the embryological development of Denonvilliers' fascia. Seven of these embryos were from our embryological collection and the other four embryos from the Department of Embryology, The Carnegie Institution of Washington, Baltimore, Maryland. Additional studies were made on dissected pelves of a 7, 8, and 9 month fetus and 2 newborn infants.

The composition and extent of this fascia in the adult were ascertained by a study of: (1) Four specimens in which the anterior wall of the rectum, the posterior part of bladder and prostate, and the seminal vesicles were removed as a unit at autopsy, fixed, and sectioned in various planes. (2) Eight pelves from middle-aged, embalmed cadavers were transected in various planes and then dissected. (3) Slides of normal and pathological prostates, from the department of pathology, were studied to determine the structure of the prostatic capsule and its relation to Denonvilliers' fascia.

In order to ascertain the position, form, and extent of this fascia encountered in the perineal approach to the prostate, an unembalmed cadaver was placed in position for perineal prostatectomy on the Young perineal table, and the "Young approach" was made to expose the prostate. Subsequently this cadaver was embalmed and its pelvis bisected in the sagittal plane and dissected. Sections taken from the various fascial layers were stained with Mallory's connective tissue stain and studied histologically to be certain that artificial cleavage planes were not made in dissect-

[1] Crown-lump length.

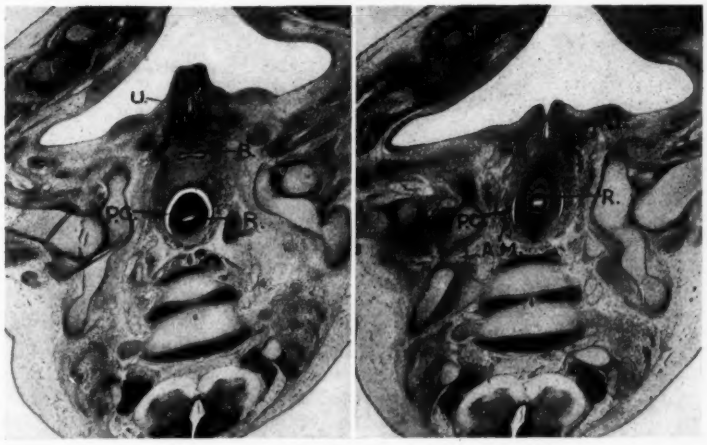


Fig. 3, left. Photomicrograph of a transverse section through the pelvis of a 19.5 millimeter human embryo. Both developing rectum, *R*, and bladder, *B*, are surrounded by mesenchyme. The peritoneal cavity, *P.C.*, intervenes between these layers of mesenchyme and surrounds three sides of the developing rectum. The position of the urethra, *U*, is shown. (U. of R. Embryo No. 30, slide 57, row 4, section 3.) ×14.

Fig. 4. Photomicrograph of a more caudal, transverse section of the embryo shown in Figure 3. The peritoneal cavity, *P.C.*, extends caudally to the level of the developing levatores ani muscles, *L.A.M.*, at the lower end of the rectum, *R*. This section is below the level of the bladder. The course of the urethra, *U*, is shown. (U. of R. Embryo No. 30, slide 58, row 3, section 6.) ×14.

ing these layers. The composition of "the glistening layer" over the posterior surface of the prostate was determined by similar histological sections from biopsy of this tissue during perineal prostatectomy in the living.

## ANATOMY OF DENONVILLIERS' FASCIA

*A. Embryology.* The rectum, pelvic urogenital organs and their connective tissues were not differentiated sufficiently in the three younger embryos studied (6, 6.5, and 7.7 mm. C.R.L.) to determine the tissues that would form the future Denonvilliers' fascia. The peritoneal cavity in these embryos, however, was observed to extend caudally to the developing pelvic floor.

More advanced differentiation of the pelvic organs and the anlage of Denonvilliers' fascia were found in older embryos (16.5, 19.5, 26, 58, 67, 70, 140, and 161.4 mm. C.R.L.). In these specimens, three layers of tissue were present between the rectum and pelvic urogenital organs: (1) a layer of mesenchyme surrounding the epithelium at the site of the developing bladder, seminal vesicles and prostate; (2) another layer of mesenchyme around the developing rectum; and (3) between these two layers of mesenchyme, the pelvic continuation of the peritoneal cavity, consisting of a mesothelium-lined sac surrounded by a thin layer of subjacent mesenchyme. The pelvic cul-de-sac of peritoneum extended caudally to the pelvic floor and laterally around the sides of the rectum in younger embryos (Figs. 3 and 4). In older embryos the mesenchyme from the cul-de-sac of peritoneum was found behind the developing seminal vesicles and prostate (Figs. 6 and 7).

The mesenchyme surrounding the pelvic urogenital organs and rectum differentiated primarily into the musculature and connective tissue associated with the epithelial lining of these structures in older embryos (Figs. 8 and 9).

Our attention will be focused particularly on the connective tissue derivatives of this mesenchyme, and that part of the peritoneal cul-de-sac which becomes associated with this connective tissue to form Denonvilliers' fascia in the adult.

Fig. 5. Sagittal section through pelvis of 26 millimeter embryo showing mesenchyme around bladder, *B*, ejaculatory duct, *E.D.*, and rectum, *R*. Peritoneal cavity, *P.C.*, extends between structures, lower part is becoming obliterated. Cyst-like areas remain where mesothelial surfaces have not fused. (Carnegie Inst. Embryo 405, slide 12, row 2, sec. 2.) ×44.

With growth and change in position as well as functional distention of the pelvic viscera, the caudal end of this cul-de-sac of peritoneum was progressively obliterated by approximation and fusion of the two mesothelial surfaces. Cyst-like areas of mesothelium remained where fusion of these surfaces was not complete (Fig. 5). It is apparent, therefore, that the peritoneal cavity did not extend as an open sac as far as the pelvic floor in older embryos. In the younger embryos of this study, the levels of fusion of the peritoneal surfaces were the same as those given by Wesson (1922). However, whereas he stated that the peritoneum only extends to the middle of the seminal vesicles in the 240 millimeter embryo, we found that the peritoneum covered the posterior surface of the prostate at this age and in older embryos (Fig. 12).

The mesenchyme originally subjacent to the mesothelial surfaces remained and differentiated into a fibrous membrane. This membrane had the same relation to the connective tissue around the rectum and pelvic urogenital organs as the original layers of the cul-de-sac of peritoneum. The development of this fibrous layer could be demonstrated in sections from the embryos of various ages.

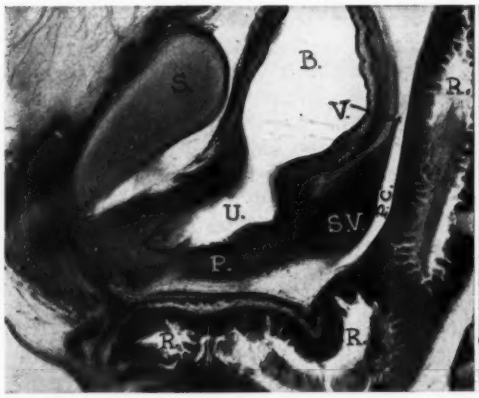


Fig. 6, left. Photomicrograph of a sagittal section through pelvis of 67 millimeter human embryo. In this specimen, the developing prostate, *P*, and seminal vesicles, *S.V.*, are imbedded in a layer of connective tissue. The peritoneal cavity, *P.C.*, extends between the rectum, *R*, and the vas deferens, *V*, and seminal vesicles. The caudal end of the peritoneal cavity, between the prostate and rectum, has been obliterated and consists only of a layer of connective tissue. The position of the symphysis pubis, *S*, and urethra, *U*, are indicated. (Carnegie Inst. Embryo No. 1656, slide 48.) ×12.

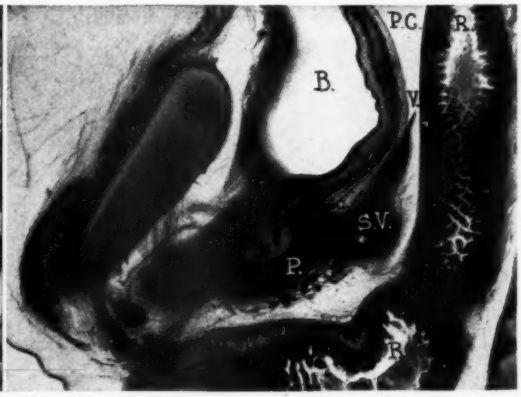


Fig. 7. Photomicrograph of more lateral section from embryo shown in Figure 6. Note that the peritoneal cavity, *P.C.*, in this section does not extend between the seminal vesicles, *S.V.*, and rectum, *R*, but connective tissue, derived mainly from the peritoneum, is found between these structures. Other labels are the same as in Figure 6. (Carnegie Inst. Embryo No. 1656, slide 49.) ×12.

In young embryos, the peritoneum covered the entire posterior surface of the seminal vesicles, apparently due to the lateral growth and increase in the transverse diameter of the pelvis and peritoneal cavity. With increasing age the peritoneum here, like that posterior to the prostate, underwent the same changes and formed a fibrous membrane (Fig. 7).

In all the embryos studied, the pelvic peritoneum covered only the posterior surface of the prostate and was not found to extend around its sides or anterior surface. In describing the tissue in these locations, Denonvilliers must have had in mind connective tissue derived from mesenchyme which surrounded the prostate and became adherent to the sides of the prostatoperitoneal membrane, since this membrane covered only the posterior surface of the prostate. However, the pelvic cul-de-sac of peritoneum did surround three sides of the developing rectum, being absent only along its sacral border (Fig. 3).

A similar cul-de-sac of peritoneum extended between the rectum and uterus in developing female embryos (Fig. 10). The homologue of Denonvilliers' fascia in the adult female will be described in a separate report.

*B. Infant.* In the full term fetus or newborn infant (Figs. 11 and 12), the connective tissues surrounding the prostate and rectum were differentiated but were not as dense as those of the adult. The peritoneal cul-de-sac was closed more cephalad due to pressure on it from the growth and distention of the pelvic organs anteriorly and posteriorly. With cephalolaterad growth of the seminal vesicles, the peritoneum may extend for a short distance between the bladder and seminal vesicles (Fig. 12). The fibrous membrane, remaining from the fused portion of the cul-de-sac of pelvic peritoneum, extended from the pelvic floor to the peritoneum covering the pelvic

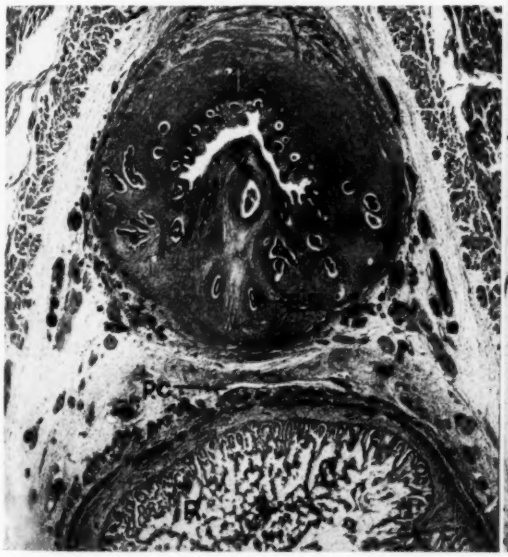


Fig. 8, left. Photomicrograph of a transverse section through prostate and rectum of 140 millimeter human embryo. The peritoneal cavity, *P.C.*, extends between rectum, *R*, and lower part of the prostate, as shown by this level cut through the verumontanum, *V*, and ejaculatory ducts, *E.D.* The musculature and connective tissue around the prostate and rectum are differentiated. (U. of R. Embryo No. 183, slide 3, row 1, section 3.) ×16.

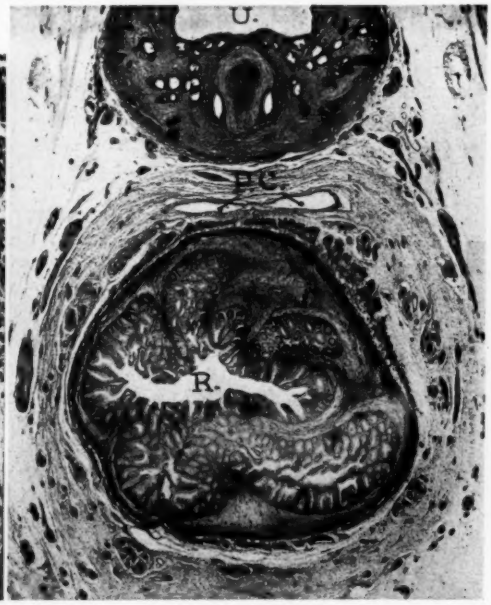


Fig. 9. Photomicrograph of a transverse section through the prostate and rectum of a 161.4 millimeter human embryo. The peritoneal cavity, *P.C.*, between the connective tissue around the rectum, *R*, and prostate is partly obliterated and does not extend as far caudally as it is found to extend in the younger human embryos. *U*, Urethra. (Carnegie Inst. Embryo No. 1049, slide 82, row 1, section 1.) ×14.

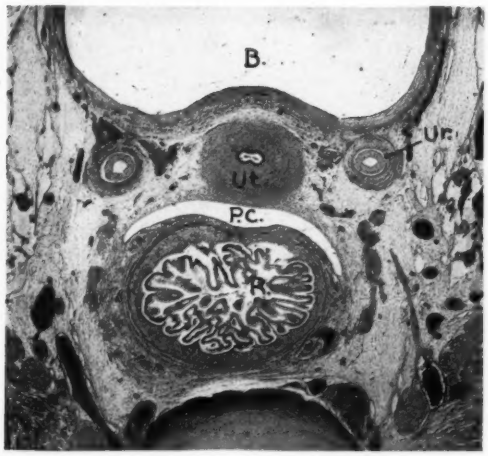


Fig. 10. Photomicrograph of a transverse section through the pelvis of a 70 millimeter female human embryo. The peritoneal cavity, *P.C.*, extends between the connective tissue around the rectum, *R*, and uterus, *Ut.*, just as it is found between the prostate and rectum of the male embryo. *B.*, Bladder; *Ur.*, ureter. (U. of R. Embryo No. 229, slide 2, row 1, section 3.) ×14.

viscera in most of the specimens. In one newborn infant the caudal end of the cul-de-sac was closed up to the middle of the prostate.

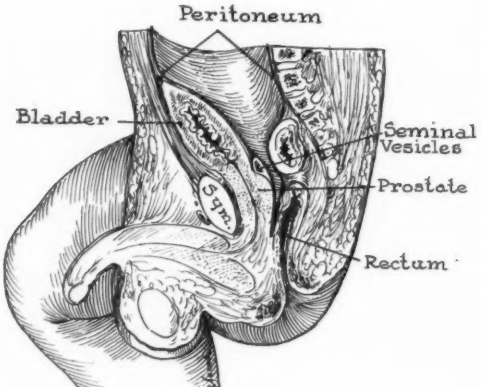


Fig. 12. Drawing, median view, from the pelvis of a full term fetus. The pelvic cul-de-sac of peritoneum extends between the seminal vesicles, prostate, and rectum and also between the upper part of the seminal vesicles and bladder. ½ normal size.

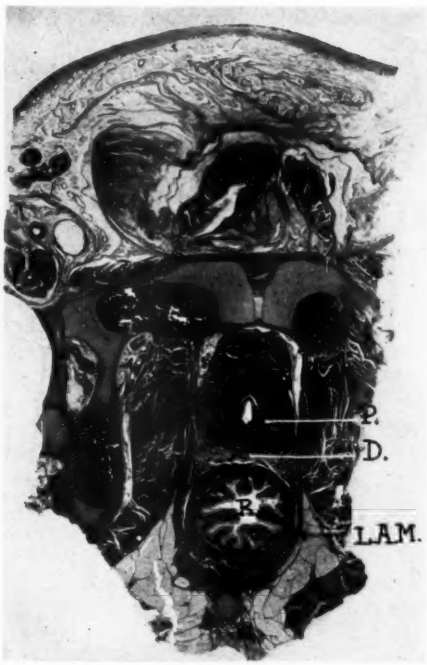


Fig. 11. Photomicrograph of a transverse section through the pelvis of a full term fetus. The layers of Denonvilliers' fascia, *D*, are formed by the connective tissue around the rectum, *R*, and prostate, *P*, and that from the obliterated cul-de-sac of pelvic peritoneum. Note relation of levatores ani muscles, *L.A.M.*, to rectum and prostate. (Carnegie Inst. Embryo No. 2409, slide 99, section 1.) ×1.6.

*C. Adult.* Between the posterior surface of the seminal vesicles, bladder, and prostate, and the anterior surface of the rectum, the following tissues were encountered: (1) A layer of rectal fascia (areolar or fatty tissue) was found immediately external to and mingled with the external longitudinal musculature of the rectum. The amount of adipose or areolar tissue in this fascia depended on the body-type of the individual (Figs. 14, 15, and 16). Clinically this layer has been described as the posterior layer of Denonvilliers' fascia. (2) Anterior to the connective tissue around the rectum, there was a fibrous membrane, the remains of the connective tissue from the cul-de-sac of peritoneum, which extended from the pelvic floor to the peritoneum covering the cephalic surfaces of the pelvic organs. This fibrous membrane was very thin in some

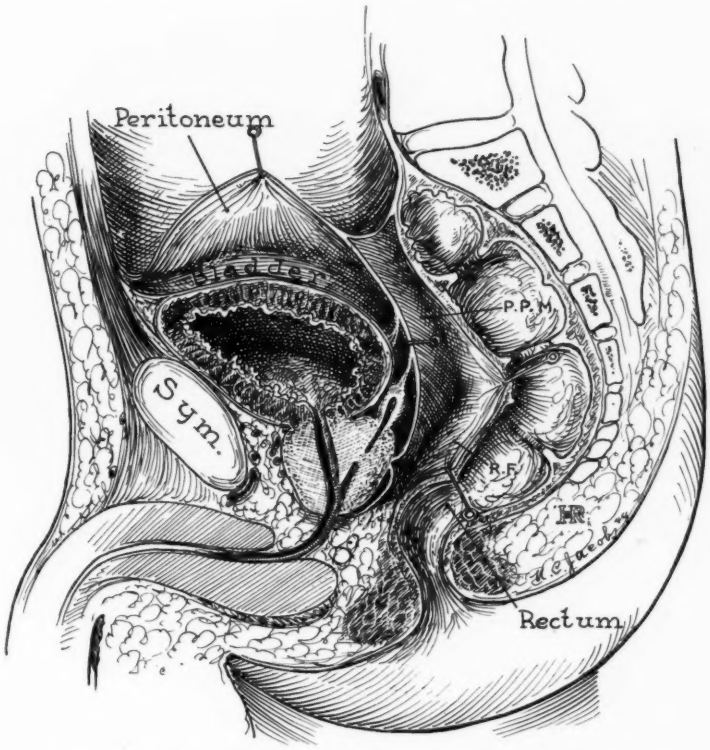


Fig. 13. Drawing of median view (right half) of adult male pelvis. The rectum and its fascia, *R.F.*, have been retracted posteriorly. The peritoneum is retracted cephaliad from the vertex of the bladder and the prostatoperitoneal membrane (anterior layer of Denonvilliers' fascia, *P.P.M.*) is retracted posteriorly from the prostate and seminal vesicles. This layer extended from the inferior surface of the prostate to the pelvic peritoneum. Fibrous bands extended from the membrane to the cephalic border of the seminal vesicles and to the bladder. The lateral parts of the membrane extend around the sides of and fuse with the rectal fascia. ½ normal size.

specimens; while in others, it was quite thick. It usually had the form of a "V," as described by Denonvilliers (1836 and 1837). The apex of the "V" was attached to the superior layer of the urogenital diaphragm at the inferior border of the prostate and the two limbs of the "V" separated as they ascended dorsolaterad to cover the posterior surfaces of the seminal vesicles (Figs. 13, 15, 20, 21, and 22). At the junction of the ampullae and ejaculatory ducts to the prostate, this fibrous membrane was fused to the prostatic capsule (Fig. 20). The clinical importance of this fusion will be discussed. The connective tissue around the sides and front of the prostate, which was derived from mesenchyme surrounding the neck of the bladder, adhered to the sides of the prostatoperitoneal membrane. Other fibrous sheets, of similar structure and also differentiated from the cul-de-sac of peritoneum, extended from the cephalic border of the seminal vesicles and posterosuperior surface of the bladder to the pelvic peritoneum (Figs. 13, 15, 20, and 21).

This fibrous membrane extended laterally around the sides of the areolar or adipose tissue of the upper part of the rectum in the adult as lateral extensions of the arms of the "V" (Figs. 13, 21, and 22). The relation of the pelvic cul-de-sac of peritoneum in the embryo,

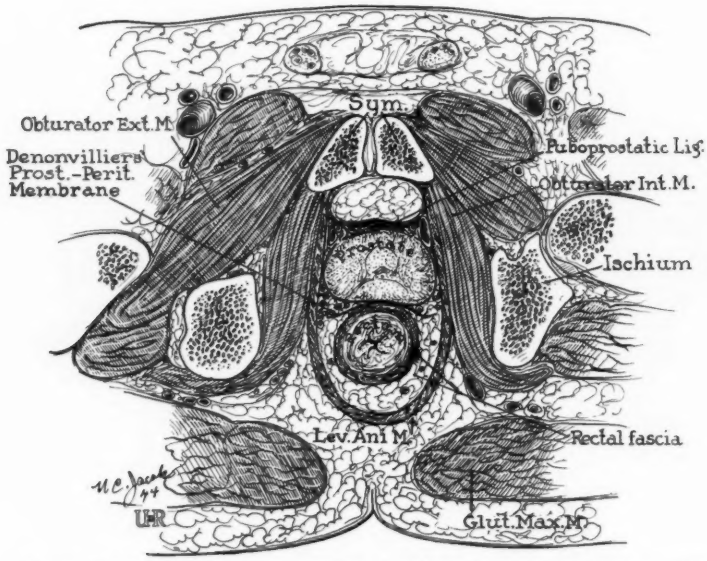


Fig. 14. Drawing from transverse section of adult male pelvis, cephalic view. This section shows the position of the rectal fascia (adipose and fibrous tissue) around the rectum; the relationship of the levatores ani muscles to the rectum and prostate and the position of the prostatic capsule. The prostatoperitoneal membrane (anterior layer of Denonvilliers' fascia) is fused to the prostatic capsule dorsal to the posterior lobe of the prostate. The retropubic pad of fat, anterior to the prostate, is in the space of Retzius. ½ normal size.

which differentiated into this part of the fibrous membrane around the rectal tissue in the adult, is shown in Figure 3.

The thickest part of this fibrous membrane was found over the posterior surface of the prostatic capsule. When well developed it was white and glistening in appearance. However, where it extended over the posterior surface of the seminal vesicles and laterally around the sides of the rectal fascia, this membrane was much thinner, more areolar than fibrous in structure, and grayish in color (Figs. 15, 16).

Denonvilliers described this membrane as being similar to the dartos and stated that it contained muscle fibers at its lateral sides in "vigorous" individuals. Histological sections taken from various regions of this membrane, contained scattered bundles of smooth muscle fibers intermingled with the collagenous and elastic fibers of the membrane (Fig. 19). The embryological origin and the functional and clinical significance of the smooth muscle in this membrane are not clear at present.

## DISCUSSION

The two opposing views of the embryological origin of Denonvilliers' fascia, i.e., entirely from mesenchyme (Wesson, 1922 and 1923) or entirely from parts of the pelvic portion of the peritoneum (Cunéo and Veau, 1899, Smith, 1908, and others) appear to be due to the differences in the concept of the tissues making up the peritoneum. In the embryo as well as in the adult the peritoneum (as defined in the standard texts of histology) consists of a surface layer of mesothelial cells and a subjacent layer of mesenchyme, or connective tissue, which supports the mesothelial layer and contains the vessels and nerves of the peritoneum. As we have shown, the developing embryo has a connective tissue layer around the rectum, a similar layer around the prostate, seminal vesicles, and bladder. Between these two visceral layers there is a continuation of the peritoneum, composed of a mesothelium lined cavity surrounded by a subjacent layer of connective tissue. Therefore, one encounters four layers

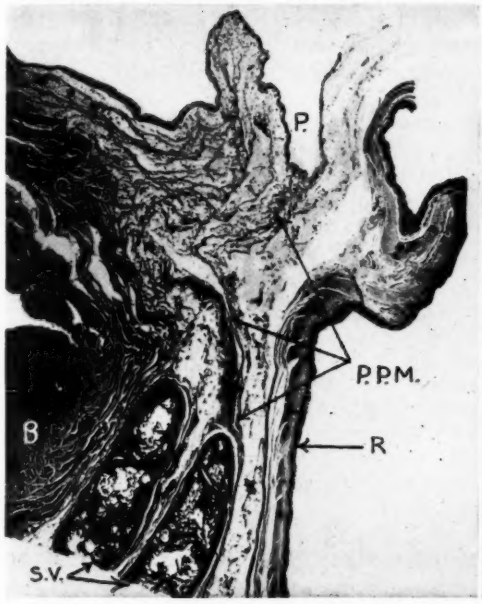


Fig. 15. Photomicrograph of a sagittal section from a block containing the anterior rectal wall, *R*, posterior part of the bladder, *B*, upper part of the seminal vesicles, *S.V.*, and peritoneal cavity, *P*. Note the continuation of the prostatoperitoneal membrane or anterior layer of Denonvilliers' fascia, *P.P.M.*, indicated by arrows extending inferiorly from the peritoneum, *P*, to a point where it comes to lie posterior to the fibromuscular covering of the seminal vesicles. Between this membrane and the rectal musculature is a layer of areolar tissue, the rectal fascia. ×2.9.

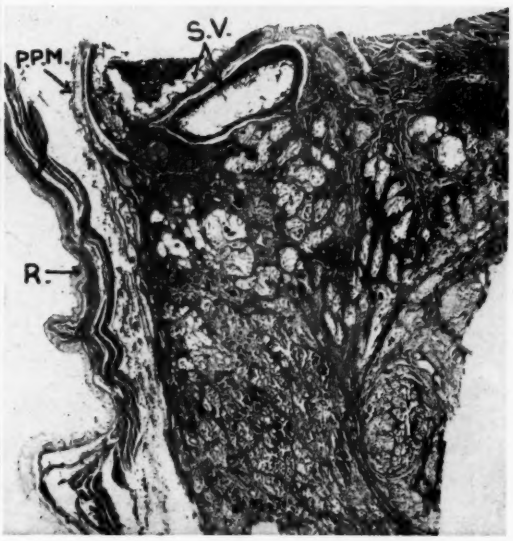


Fig. 16. Photomicrograph of a sagittal section from a block containing the anterior wall of the rectum, *R*, prostate, *P*, base of the seminal vesicles, *S.V.*, and part of the bladder musculature, *B*. The prostatoperitoneal membrane or anterior layer of Denonvilliers' fascia, *P.P.M.*, is thin and closely applied to the prostatic capsule but is separated from rectal musculature by areolar rectal fascia. Note continuation of fibromuscular tissue of prostate around and over base of seminal vesicles. The glandular epithelium of prostate is very near the prostatic capsule. ×4.17.

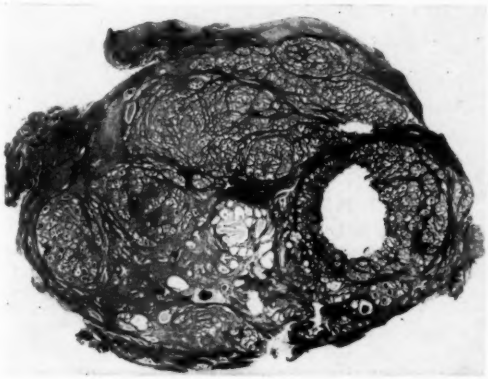

Fig. 17. Photomicrograph of prostatic tissue showing increase in amount of fibromuscular tissue on the surface and around the areas of benign prostatic hypertrophy in left side and lower right half of section. ×3.5.

Fig. 18. Photomicrograph of prostatic tissue showing decrease or absence of fibromuscular tissue around the areas of cancer. Compare right and left parts of section and with Figure 17. ×3.5.

Fig. 19. Photomicrograph of a section through the prostatoperitoneal membrane of Denonvilliers (anterior layer of Denonvilliers' fascia), taken near the posterior inferior surface of the prostatic capsule. The bundles of smooth muscle are seen coursing in the areolar tissue of this layer. ×70.

of connective tissue in the region of the developing Denonvilliers' fascia—two layers associated with the viscera and two others, one on each side of the mesothelium of the pelvic peritoneum. Depending on the concept one has of the layers of tissue making up the peritoneum, it can be understood readily how the mesenchyme, remaining from the regression and disappearance of the mesothelial layers during closure of the peritoneal cul-de-sac, could be interpreted as part of the mesenchyme around the viscera; or all of the pelvic mesenchyme could be interpreted as part of the peritoneum. The fusion of the mesothelial surfaces of the cul-de-sac of peritoneum may be due partly to the change in position of the bladder as well as to its growth and functional distention. Disse (1892) described the descent of the bladder as being rapid during the first 3 years; slower from the 4th to 9th years, with little change in position between that age and puberty; after which the descent is renewed and the bladder gains its final position at the pelvic floor by the 21st year.

When two peritoneal surfaces are approximated in the embryo, through change in position of the viscera, the mesothelial surfaces become adherent, retrogress, and disappear. The connective tissues associated with the mesothelial surfaces remain, however, as fibrous sheets. Toldt (1893) described this process for the peritoneal surfaces associated particularly with the intestine. According to our studies, the pelvic cul-de-sac of peritoneum underwent similar changes. Furthermore, a fold of peritoneum was found between the bladder and seminal vesicles during development of the pelvic organs (Fig. 12). This peritoneum was external to the fibromuscular covering of the seminal vesicles, and in older specimens formed only a fibrous strand extending from the cephalic borders of the seminal vesicles and posterosuperior border of the bladder to the pelvic peritoneum. These studies also agree, therefore, with those of Smith (1908) and Cunéo and Veau (1899) who stated that the tissue between the bladder and seminal vesicles was derived from the peritoneum.

Our studies indicate that the only part of Denonvilliers' fascia to be derived from peritoneum was the fibrous membrane remaining after obliteration of the cavity in the pelvic cul-de-sac of peritoneum. This membrane was located between the loose connective tissue around the rectum and the more dense fibromuscular connective tissue around the prostate and seminal vesicles. Contrary to Wesson's view that the peritoneum reverts to undifferentiated tissue in the embryo, we found the fibrous membrane derived from the peritoneum to be present in all of the adult specimens and its origin could be traced in the variously aged embryos and fetuses studied. This membrane in the adult was nearer the prostate than the rectum—being close to, and in certain areas adherent to, the fibromuscular covering of the prostate. A layer of areolar or adipose tissue (rectal fascia) intervened between this membrane and the rectal musculature. If the mesothelial surfaces persist, the cul-de-sac might remain open and form a direct connection with the peritoneal cavity. Herniation into a pelvic continuation of the pouch of Douglas is known to occur (Callander, 1939). Cyst-like areas could be formed where the mesothelial surfaces remain be-

Fig. 20. Drawing, sagittal, pelvic section of a male cadaver in which the Young prostatic approach was made. The anus and lower part of the rectum are retracted dorsally within the incision. In this approach the rectal fascia was divided—part of it is still attached to the central point of the perineum; the remainder covers the cephalic portion of the rectum. The peritoneum is elevated from bladder and cephalic portion of the rectum. The anterior layer of Denonvilliers' fascia is attached to the peritoneum and extends caudally between the seminal vesicles and prostate and rectal fascia, to the superior layer of the urogenital diaphragm. This membrane adheres to the prostatic capsule at the junction of the ejaculatory ducts to the prostate. Other fibrous bands extend from the peritoneum to the seminal vesicles and bladder. As indicated by the arrows, cleavage planes may be made between: *1*, the rectal musculature and rectal fascia (posterior layer of Denonvilliers' fascia); *2*, the rectal fascia and the anterior layer of Denonvilliers' fascia; and *3*, either this anterior fascial layer and the fibromuscular coverings of the seminal vesicles or it and the prostatic capsule. A sound is passed through the urethra but the prostate is not shown retracted dorsally by the sound. When the prostate is so retracted these fascial layers are compressed against the rectal musculature and dissection may lead into the rectum. ½ normal size.

Fig. 21. Oblique view of the sagittal section from a male pelvis. The cephalic portion of the rectum is removed to show the rectal fascia covered by the lateral part of the anterior layer of Denonvilliers' fascia. This layer is retracted posteriorly and the seminal vesicles retracted anteriorly to show the posterior coverings of the seminal vesicles. The anterior layer of Denonvilliers' fascia and fibrous sheets from the seminal vesicles and bladder are attached to the pelvic peritoneum. ½ normal size.

tween the prostate or seminal vesicles and the rectum.

The connective tissue around the rectal musculature and that around the epithelium of the seminal vesicles and prostate, is derived from the mesenchyme surrounding these structures in the embryo. Since the seminal vesicles are an outgrowth of the mesonephric duct near the developing prostate, and since this region is imbedded in a common layer of mesenchyme (Figs. 3, 5, 6, and 7), the fibromuscular connective tissue is continued around the prostate and seminal vesicles (Fig. 16).

Histological sections through the prostate of the young or old male contained a definite layer, composed of smooth muscle and collagenous and elastic connective tissue, which formed an outer covering and framework for the glandular cells of the prostate and seminal vesicles. This tissue not only was continuous within the substance of the prostate and the seminal vesicles but also invested these glands. It has been stated that the covering of the prostate might be continuous with that of the bladder (Van Duzen, Looney, and Duncan, 1939) and therefore the prostate could be considered as a gland at the neck of the urinary bladder.

As Wesson (1922) and others have suggested, the capsule of the prostate can be compared to the capsule of the liver or spleen—a surface layer of connective tissue surrounding an organ that is continuous with the connective tissue septa extending into the glandular portion of the organ. Our studies agree with this concept; for where the glandular tissue was very near the surface of the fibromuscular covering, a distinct capsule could not be dem-

onstrated histologically in many sections of prostates (Fig. 16). In some sections of prostates showing benign hypertrophy, the fibromuscular tissue on the surface and within the substance of the gland was increased (Fig. 17). However in several sections of the prostate involved by cancer (Fig. 18), the fibromuscular septa and the capsule were invaded, displaced or replaced by adenocarcinomatous tissue. The latter condition could alter the glistening appearance of the fibromuscular layer of the prostate.

This fibromuscular tissue surrounding and permeating the glandular components of the prostate and seminal vesicles may be attached to, or fused with, the anterior layer of Denonvilliers' fascia. The question then arises, what is the anterior layer of Denonvilliers' fascia and which tissues form the tough, glistening layer, "the pearly gates," over the posterior surface of the prostate? Is it the remains of the peritoneal cul-de-sac, together with the fibromuscular coverings of the seminal vesicles and prostate, or merely the fibromuscular covering of these structures? Some descriptions of the perineal approach to the prostate intimate that the so called prostatic capsule and Denonvilliers' fascia may be the same structure.

Our studies show that there are two layers of tissue covering the glandular elements on the posterior part of the prostate, after the rectum and its fascial covering have been retracted. The membrane of fibrous tissue remaining from the cul-de-sac of peritoneum covering the posterior surface of the prostate, if well developed, was thick and whitish in appearance. When this layer was incised and retracted, the fibromuscular covering over the posterior surface of the prostate was exposed. The latter layer was also whitish and thick, particularly in cases of benign prostatic hypertrophy. Therefore, either the fibrous membrane or the fibromuscular covering of the prostate, which usually were close together and were adherent at some points, might form the glistening, white layer known as the "pearly gates." However, histological preparations of tissue taken from the glistening, white layer during perineal prostatectomy consisted only of fibromuscular and glandular

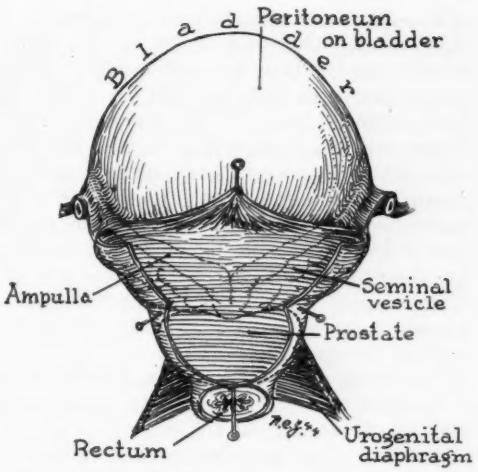


Fig. 22. Diagram of dorsal view of the anterior layer of Denonvilliers' fascia. This anterior layer extends from the base of the prostate to the pelvic peritoneum between the rectum and bladder. It covers the posterior surfaces of the prostate and seminal vesicles and lateral extensions of this anterior layer cover the sides of the rectal fascia (posterior layer of Denonvilliers' fascia). The upper part of the rectum and rectal fascia have been removed and the lower part of the rectum retracted posteriorly from the anterior layer of Denonvilliers' fascia. The peritoneum covering the upper part of the rectal fascia is retracted forward. 3/5 normal size.

prostatic tissue. Therefore, in many perineal prostatectomies the anterior layer of Denonvilliers' fascia may be retracted backward with the posterior layer (rectal fascia) in the development of the incision (space *1* of Fig. 20). The glistening layer, in such instances, would be no more than the fibromuscular covering of the prostate.

Our findings also agree with Denonvilliers' description of the fusion of the prostatoperitoneal membrane with the connective tissue around the prostate forming a closed compartment around the base of the bladder (Fig. 22).

Sections from various parts of the prostate, and from the fibrous membrane posterior to the prostate, indicated that part of the blood supply of the prostate courses in the fibromuscular covering and not in the fibrous membrane, agreeing with Flocks' (1943) description of the vascular supply of the prostate.

The importance of Denonvilliers' fascia as an anatomic landmark in perineal surgery is well demonstrated by the frequent reference

to this structure in the literature. However, a more detailed anatomic study of this fascia permits one to stress its relationship to other pelvic structures and especially to utilize the three potential spaces which can be developed during perineal surgery (Fig. 20). It becomes evident that if space *1*, between the rectal fascia and rectal musculature (Fig. 20) is entered inadvertently, one may damage the rectal wall or even enter the lumen of the rectum. On the other hand, the rectal fascia constitutes a layer which can be used advantageously in the repair of rectal tears and recto-urethral fistulas (Scott, 1935).

The fascia around the external rectal musculature may be areolar or both areolar and adipose, depending on the body type of the individual. This layer has been described as the thicker, posterior layer of Denonvilliers' fascia and is the cleavage plane used in freeing and retracting the rectum backward in the perineal approach to the prostate. Although Denonvilliers did not describe this tissue as part of the prostatoperitoneal membrane but only stated (Fig. 2): ". . . La face inférieure qui touche au rectum lui adhère à peine par un tissu cellulaire très-lâche . . . ,"; therefore, by definition it should not be included in Denonvilliers' fascia. However, since this tissue is considered as part of Denonvilliers' fascia in the clinical literature and for the sake of simplicity, we suggest this fascia around the rectum be designated the posterior layer of Denonvilliers' fascia. The fibrous membrane derived from the cul-de-sac of peritoneum could be designated, therefore, the anterior layer of Denonvilliers' fascia. This terminology would help to clarify the descriptions of these fascial layers.

With the surgical development of spaces *2* or *3* (Fig. 20), the urological surgeon can have access to the prostate gland or seminal vesicles. It may be pointed out that if a sound or retractor is passed per urethram (Geraghty, 1922; Johnson, 1940; Lowsley, 1940 and others) or if an instrument is passed per rectum (Foley, 1929), the layers between the prostate and rectum were so compressed by pressure in our specimens as to render the separation of the natural cleavage planes in these layers more difficult (Fig. 20). In this respect the procedure of Belt and coworkers (1939) offers some advantages, since it does not use an instrument per urethram or per rectum in the first stage of the operation and therefore allows more space for dissection between the fascial layers.

Since cancer usually arises in the posterior lobe or may arise in any portion of the prostate (Moore, 1935; Rich, 1935; Kahler, 1939 and others), the fibromuscular covering over the prostate and seminal vesicles becomes an important barrier in limiting the spread of cancer. After direct extension through the prostatic capsule or into the region of the seminal vesicles and bladder, the layers of Denonvilliers' fascia would become the next line of defense (Figs. 20 and 22) in preventing the cancer from spreading posteriorly to the rectum. Furthermore spaces *2* and *3* shown in Figure 20, or both of these spaces, may direct the flow of pus or urine extravasated from a ruptured prostatic abscess, particularly the small pocket at the posteroinferior border of the prostate formed by the connection of the fibrous membrane (anterior layer of Denonvilliers' fascia) to the posterior surface of the prostate at the level of the ejaculatory ducts.

The lithotomy position of the patient upon the surgical table may be varied greatly—from one in which the perineum is at an angle of approximately 45 degrees with the floor, to the other extreme wherein the perineum is parallel with the floor. Belt and associates (1939) and Johnson (1940) use the latter position, whereas Young (1926) and others use intermediate positions. It would appear from the standpoint of the anatomical location of the pelvic viscera and their fasciae, that the Belt and Johnson procedures have the advantages of adjusting the pelvic structures to allow the surgeon to see the rectal fascia at all times and hence reduce the liability of rectal tears. Furthermore, the extreme lithotomy position would bring the prostate closer to the surface of the perineum.

## CONCLUSIONS

1. The tissue known clinically as Denonvilliers' fascia was observed to be derived embryologically from two sources of connective tissue (mesenchyme): (1) a layer surrounding

the developing prostate and seminal vesicles and another layer around the rectum; and (2) connective tissue (mesenchyme) adjacent to the mesothelium of the pelvic cul-de-sac of peritoneum. This peritoneal cul-de-sac extended to the level of the developing levatores ani muscles in young embryos.

2. The connective tissue around the seminal vesicles and prostate differentiates into the fibromuscular covering and framework continuous over both of these structures. That around the rectum differentiates mainly into the areolar or adipose tissue and musculature around the rectal mucosa.

3. With growth, change in position, and distention of the pelvic viscera, the caudal part of the cavity in the pelvic cul-de-sac of peritoneum was obliterated progressively by approximation, fusion, and disappearance of the mesothelial surfaces. The connective tissue adjacent to the mesothelium remained as a fibrous membrane throughout development and was present in the adult.

4. The fibrous membrane derived from the pelvic cul-de-sac of peritoneum contained bundles of smooth muscle fibers. This membrane was "V" shaped and extended from the inferior border of the prostate to the pelvic peritoneum. The arms of the "V" extended laterally behind the seminal vesicles and on the sides of the areolar or adipose tissue around the rectal musculature. This membrane was near to the fibromuscular coverings of the seminal vesicles and prostate and fused with the prostatic covering at the junction of the ejaculatory ducts with the prostate. The endopelvic connective tissue (fascia) fused with the lateral sides of this fibrous membrane.

5. Fibrous bands, also derived from the pelvic cul-de-sac of peritoneum which during development intervenes between the seminal vesicles and the bladder, extended from the superior border of the seminal vesicles and posterosuperior surface of the bladder to the peritoneum.

6. We suggest that the fascia around the rectal musculature be designated the posterior layer, and that the fibrous membrane, which is derived from the pelvic cul-de-sac of peritoneum, be designated the anterior layer of Denonvilliers' fascia.

7. In the perineal approach to the prostate, three potential, fascial spaces could be developed between the rectum and prostate: (1) between the rectal musculature and rectal fascia (posterior layer of Denonvilliers' fascia); (2) between the rectal fascia and anterior layer of Denonvilliers' fascia; and (3) between the anterior layer of Denonvilliers' fascia and the fibromuscular covering of the prostate and seminal vesicles.

8. Since the anterior layer of Denonvilliers' fascia and the fibromuscular covering of the prostate were whitish in appearance and were close together or adherent, either or both of these layers may constitute the glistening layer encountered in the perineal exposure of the prostate.

9. If the fibromuscular covering of the prostate were perforated by cancer or abscess, the fibrous membrane (anterior layer of Denonvilliers' fascia) may prevent direct spread of the malignant growth posteriorly to the rectum and may limit the spread of extravasated pus or urine.

10. The fascial spaces between the rectum, prostate, and seminal vesicles were separated more readily in our specimens if they were not compressed by instrumentation per urethram or per rectum in the first stages of the perineal approach.

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# THE FUNCTION OF THE PATELLA AND THE EFFECTS OF ITS EXCISION

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IT seems likely that more has been written about the patella, relative to its size, than about any other bone in the human body, and yet in spite of this there is no uniformity of view regarding its function. Lockhart described it as a lever and a roller bearing in the quadriceps tendon. Lickey, quoted by Brooke (5), attributed to the patella the function of a rocking lever whose fulcrum shifts distally as the knee joint moves from flexion to extension. Duboux indicated a similar conception when he compared the patella to a gearbox which reduces movement and increases power. Walmsley, Mackenzie, and Jamieson, all referred to it as a mechanical aid to the leverage of the quadriceps. Similarly, Bowen, Grant, and Thomson expressed the conviction that the patella holds the extensor tendon forward, away from the center of the knee joint, and so increases the leverage of its action. Thomson believed that this function is most important in the fully flexed positions of the knee. Heineck thought that the principal purpose is that of a pulley for facilitating the movements of the extensor tendon and that improvement in the leverage is a minor function. Jarecki claimed the same dual physiological rôle, but he believed that these are secondary functions, assumed in the process of evolution, and that the primary action of the bone as a block to prevent hyperextension of the knee has been lost. Bruce and Walmsley concluded from animal experiments that the patella's function is to protect the lower end of the femur against the traumatizing influence of the quadriceps tendon.

All the observers mentioned hitherto accredited the patella with a rôle of functional importance. The opposite view has, however, increased in popularity. From his case of congenital absence of both patellae with excellent knee function Wuth concluded that the patella serves no useful purpose. Murphy (28), from observations on his cases of patellectomy, considered that the bone is not essential for perfect mobility and function of the knee joint. De Vriese decided that it is undergoing phylogenetic and ontogenetic retrogression, and that it therefore plays no useful part in the body's economy. Powerful support was given to this view by Brooke (5) who claimed that his experimental and clinical investigations proved that the patella not only does not assist the action of the quadriceps on the knee joint but actually reduces its efficiency. Maróttoli made a similar claim.

In an attempt to establish the correct view of the patella's function, the fields of comparative anatomy, human embryology, human anatomy, experimental anatomy, and clinical surgery are examined.

## COMPARATIVE ANATOMY AND HUMAN EMBRYOLOGY

The study in comparative anatomy and embryology has been reported elsewhere (19), and only the conclusions will be recapitulated here. There is no evidence that the patella is undergoing phylogenetic or ontogenetic retrogression and, on the whole, the evidence supports the view that it has a functional value in extension of the knee joint.

In the field of human anatomy, the relationship of the patella to the extensor tendon of the knee has been disputed. The classical view, as expressed by Poirier, is that the quadriceps tendon is attached to the base of the patella, the patellar tendon is attached to the apex, and these tendons are connected by a thin prepatellar aponeurosis and rather thicker medial and lateral retinacula. But Bernays and Kazzendar described the bone as lying posterior to the extensor tendon and only loosely attached to it. Brooke (5) and Hey

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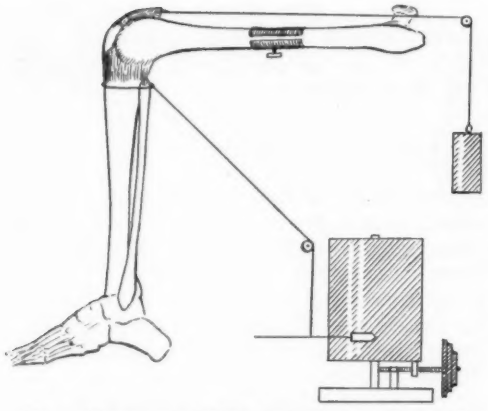

Fig. 1. Measurement of the range and speed of extension of the knee joint by a constant force.

Groves (17, 18) subscribed to this view. It must be agreed, however, by all who have performed the operation that in the removal of the patella many fibers of the patellar and quadriceps tendons must be divided, and sagittal sections of the bone and its tendons show clearly that the patella gives attachment to the vast majority of the fibers of these tendons. Therefore, the bone lies in the line of the extensor tendon and transmits the tension produced by the quadriceps. How else could it be rent asunder by sudden contractions of this powerful mass of muscle?

## EXPERIMENTAL ANATOMY

The surest way of determining the function of the patella is to study the effect which its removal has on the knee joint. To this end experimental patellectomy has been carried out in animals and human cadavers. Bruce and Walmsley, using rabbits, found degenerative changes in the patellar surface of the femur after patellectomy, and they concluded that the patella protects the femur from trauma produced by the quadriceps tendon. It is an established fact, however, that, when the articular surfaces of a synovial joint are separated, degenerative changes take place in the hyaline cartilage. This may well be the explanation of the changes observed by these investigators.

Carey, Zeit and McGrath used puppies and took special care to ensure that no perichondrium or periosteum remained in the tendon after operation. In spite of this, regeneration occurred within a few weeks, but did not do so if the knee was immobilized by arthrodesis. After arthrodesis of one knee the weight was borne chiefly on the normal hind leg, and the patella of that limb became larger than normal. These results suggest that the bone has a rôle of functional importance and they were supported by the findings of Girardi using dogs. On the contrary Brooke (5) concluded that the patella is an encumbrance which reduces the efficiency of knee extension. The following investigation was carried out in order to determine which was the correct view.

## METHODS

The knee joints of 7 cadaver limbs were mobilized by the division of all restraining structures and lubricated with a jelly so that they moved as freely as in life. Each limb was investigated in several ways at the following stages: (1) before patellectomy; (2) after removal of the patella either through a sagittal section of the bone and its tendons or, after reflexion of the quadriceps distally, by dissection of the entire bone from its bed, leaving the thin prepatellar aponeurosis intact; (3) on replacement of the patella in its bed without attachment; (4) after suture of the quadriceps and patellar tendons together, with obliteration of gap bridged by prepatellar aponeurosis.

*Extension of the knee joint by a constant force.* This investigation was similar to that of Brooke (5), with a modified apparatus (Fig. 1). The femur was clamped in a horizontal position and a pull was applied to the quadriceps tendon by a cord passing over a pulley to a hanging weight. The weight was such that under its influence the intact knee moved almost to full extension. Records of movement in each of the 4 stages mentioned were made on moving smoked paper (Fig. 2).

The law of moments states that for equilibrium the sum of the moments of a system of forces about any point must be zero. When the force of knee extension is balanced by a force acting at the ankle the conditions are as shown in Figure 3. A precise measure of the influence of the patella on the extensor apparatus of the knee should be obtained by a

TABLE I.—RANGE AND SPEED OF EXTENSION OF KNEE JOINT BY A CONSTANT FORCE—AVERAGE FOR 7 CADAVER LIMBS.

| | Angle reached—degrees | Time to reach angle *A*—seconds |
|---|---|---|
| Patella present | 167 | 0.39 |
| Patella absent | 137(A) | 0.35 |
| Patella replaced | 162 | |
| Tendons sutured | 150 | |

study of the forces *A* and *B* and the distances *x* and *y* before and after patellectomy.

*Mechanical ratios.* Spring balances were used to determine the forces, one attached to the leg just distal to the malleoli, and the other in turn to the quadriceps tendon and to the patellar tendon (Fig. 3). The position of the pulley *C* was arranged so that when the balance *D* registered 1 kilogram, the center of gravity of the leg and foot was directly below the axis of the knee joint and the cord passed from the pulley to the leg in a horizontal direction. This ensured that the moment of force *B* remained constant and was the only factor resisting extension of the knee. The femur was tilted in the clamp so that knee joint angles of 60, 90, 120, and 150 degrees were obtained, and at each of these the tensions necessary in the tendons to balance a resistance of 1 kilogram at ankle were found.

*Distance ratios.* The position of the axis of the knee joint was found by drawing the radii of curvature of the condyles on a lateral profile drawing of the lower end of the femur. These intersect in a small spiral, indicating that the curve of the articular surfaces of the condyles is not a part of a circle but of a spiral, a fact which was noted a century ago by the brothers Weber. The center of the small spiral gives a fairly accurate axis for all positions of the joint, and it coincides with the center of the femoral attachment of the lateral ligament. Measurements were made from this point to the central plane of the patellar tendon on profile drawings of the cadaver knee joints, with a dioptrograph (37), and also from same point to tip of lateral malleolus.

## RESULTS AND DISCUSSION

*Extension of the knee joint by a constant force.* The results are presented in Table 1. After patellectomy the leg stopped moving 30 degrees short of the angle reached when the patella was present. This is clear proof that the efficiency of the extensor mechanism in the more extended positions of the knee is seri-

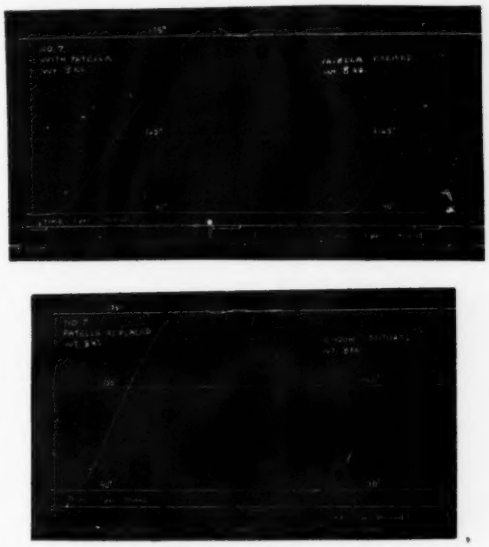

Fig. 2. Record of extension of the knee joint by a constant force.

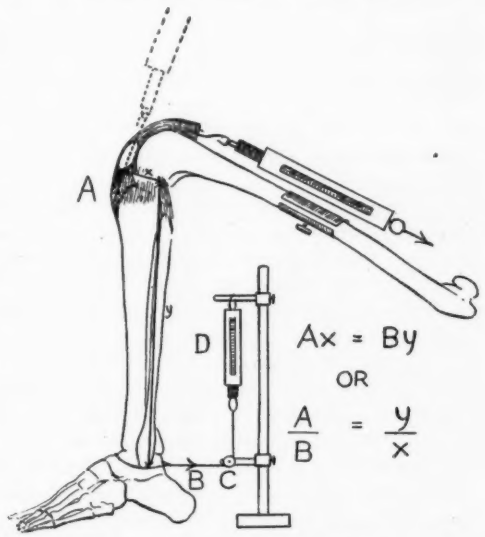


Fig. 3. The law of moments applied to the leg. Measurement of the ratios of the tensions in the quadriceps and patellar tendons to the resistance at the ankle.

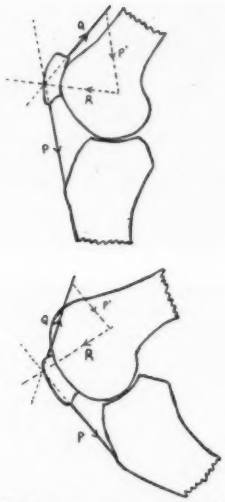


Fig. 4. The forces acting on the patella with the knee joint at 150 degrees and at 60 degrees.

ously impaired by the operation. The original efficiency was almost completely restored by reinserting the patella in its bed. Suture of the quadriceps to the patellar tendon gave a 13 degree increase in extension. This indicates that, in the more extended positions, the retinacula do not transmit the pull of the quadriceps as efficiently as does the restored central tendon. contrary to the findings of Brooke (5).

Of the efficiency of extension between 90 and 135 degrees, the best indication is the time taken before and after the removal of the patella for the leg to reach the angle at which it ceased to extend after patellectomy. This was determined from the graphs. Without exception, the time taken after the operation was less than that when the bone was present. Excision of the patella resulted in increased efficiency of knee extension, but only in the flexed positions and not, as Brooke maintained, throughout the whole range of knee movement. He reported that the leg moved at a constant speed after the initial acceleration, and this was confirmed. This finding is of significance because the resistance to the movement of extension, which is the moment of the leg's weight about the knee joint axis, increases as extension proceeds. To maintain a uniform velocity the extending moment

TABLE II.—RATIOS OF TENSIONS IN QUADRICEPS AND PATELLAR TENDONS TO RESISTANCE AT ANKLE, AT DIFFERENT KNEE JOINT ANGLES—AVERAGE FOR 7 CADAVER LIMBS

| Angle-degrees | Patella present | Quadriceps tendon | | | Patellar tendon | |
|---|---|---|---|---|---|---|
| | | Patella absent | Patella replaced | Tendons sutured | Patella present | Patella absent |
| 60 | 15.4: 1 | 14.5: 1 | 15.9: 1 | 14.5: 1 | 10.3: 1 | 12.5: 1 |
| 90 | 14.1: 1 | 13.0: 1 | 14.4: 1 | 13.0: 1 | 9.8: 1 | 11.5: 1 |
| 120 | 10.6: 1 | 12.2: 1 | 11.2: 1 | 12.0: 1 | 8.6: 1 | 10.4: 1 |
| 150 | 8.9: 1 | 12.4: 1 | 9.6: 1 | 11.5: 1 | 7.7: 1 | 10.0: 1 |

must also increase despite the fact that the pull on the quadriceps tendon is constant. Since the leg stopped moving at an earlier stage after patellectomy, this increase in the extending moment with knee extension must be reduced by the operation.

*Mechanical ratios.* The average results are given in Table II. The decrease in the ratios which accompanies knee extension confirms that the extending moment of a constant tension in the tendons increases as the joint extends. Patellectomy produced a slight decrease in the ratio for the quadriceps tension at 60 and 90 degrees, confirming that the extensor efficiency in the flexed knee is increased by the operation. But the decrease in this ratio between 60 and 150 degrees was only 14.5 per cent against the 42.2 per cent decrease before patellectomy, indicating that the patella is responsible for most of the increase in extensor efficiency which accompanies knee extension, and that its removal reduces considerably the efficiency of the movement of extension in the more extended positions.

The ratios for the patellar tendon tension were almost identical with the corresponding distance ratios (Table III); this finding confirms the application of the law of moments. At the same time, they were less than those of the quadriceps tension, and particularly was this so in the flexed positions of the knee and when the patella was present. This finding indicated that there is a loss of power in the transmission of tension in the extensor apparatus, and that the patella is largely responsible for the loss. To understand how such a freely gliding structure can cause a consider-

TABLE III.—RATIOS OF AXIS-MALLEOLAR DISTANCE, $y$, TO AXIS-TENDON DISTANCE, $x$, AT DIFFERENT KNEE JOINT ANGLES—AVERAGE FOR 7 CADAVER LIMBS

| Angle-degrees | Axis-tendon distance | | $y$ to $x$ ratio | |
|---|---|---|---|---|
| | Patella present | Patella absent | Patella present | Patella absent |
| | cm. | cm. | | |
| 60 | 3.8 | 3.25 | 10.3: 1 | 12.0: 1 |
| 90 | 4.0 | 3.5 | 9.6: 1 | 11.0: 1 |
| 120 | 4.6 | 3.8 | 8.3: 1 | 10.2: 1 |
| 150 | 5.1 | 3.9 | 7.6: 1 | 9.9: 1 |

able loss of power, the various forces acting on it must be examined.

The knee joint is considered in two positions, 150 degrees and 60 degrees (Fig. 4). The forces are the pull of the quadriceps $Q$, the tension in the patellar tendon $P$, and the reaction $R$ from the femur acting through the point of contact of the two bones. These forces pass through one point when equilibrium is present, and a triangle of forces is completed by drawing $P'$ parallel to $P$. The sides of this triangle represent the forces in relative magnitude as well as in direction. At 150 degrees, $P$ is nearly equal to $Q$, and at 60 degrees is much smaller, which confirms the experimental findings. In addition, the pressure between the patella and the femur, indicated by $R$, is greater at 60 degrees than at 150 degrees. This does not matter when the friction is negligible as it is normally, but in states such as osteoarthritis, in which the cartilage is roughened and friction is greatly increased, there is an increased loss of power, especially in the flexed positions; as was clearly shown in one of the cadaver legs. Marked patello-femoral osteoarthritis was present, and considerable improvement in the efficiency of knee extension throughout almost the whole range of movement followed patellectomy and suture of the quadriceps and patellar tendons together.

*Distance ratios.* The distance ratios indicate that the increase in the extending moment of a constant quadriceps tension, which accompanies knee extension, is due to increase in the axis-tendon distance, the distance from the knee joint axis to the central plane of the patellar tendon. This increase is due mainly to the patella moving out of the intercondylar fossa, where it lies in full flexion, on to the anterior surface of the distal end of the femur.

Fig. 5. Measurement of the power of knee extension.

## CLINICAL

The last field of study is that of the living. Good results following patellectomy have been claimed by many surgeons from Stimson onward (2, 11, 12, 27, 29, 34, 37, 40) the majority stating that after the operation the knee is functionally equal to normal. On the other hand, Heineck, Friberg, and Wass and Davies concluded that the patellectomized knee has an impaired power of extension. Brooke (4) appears to have been the only one to measure quantitatively the effect of the operation. Using a dynamometer attached to the ankle he tested the power of knee extension with the knee joint at 90 degrees and found that this was slightly greater in the leg operated upon than in its normal counterpart.

The apparatus shown in Figure 5 was used in the present study. By raising or lowering

TABLE IV.—POWER OF KNEE EXTENSION, MEASURED AT ANKLE, IN 7 NORMAL SUBJECTS AND 2 PATELLECTOMIZED

| Angle-degrees | Normal subjects | | Patient 1 | | Patient 2 | |
|---|---|---|---|---|---|---|
| | Right kgm. | Left kgm. | Right kgm. | Left* kgm. | Right* kgm. | Left kgm. |
| 60 | 32 | 30 | 32 | 31 | 15 | 24 |
| 90 | 34 | 32 | 36 | 32 | 16 | 25 |
| 120 | 43 | 41 | 44 | 33 | 18 | 31 |
| 150 | 44 | 42 | 42 | 32 | 19 | 37 |

*Denotes limb in which the patella is absent.

the cross bar supporting the thigh and also the attachment of the cord to the upright post behind the subject, and by adjusting the length of the cord between the post and the spring balance, the maximum power of knee extension could be measured for each of the four chosen joint angles, with the leg vertical and the cord horizontal. These conditions are necessary to eliminate unrecorded variations in the moment of resistance to extension. Table IV gives the average results from 7 subjects.

The power of extension increases as the knee extends. This finding is of interest in view of the law of von Schwann that the tension of contraction diminishes as muscle fibers shorten. In the case of the quadriceps the fibers are shortest in the fully extended position of the knee joint, and therefore the tension which they can produce is least in that position. The fact that the power of knee extension increases in spite of this is further proof that the extending moment of the quadriceps pull increases as the knee extends.

It would be expected from the results of the experimental work that patellectomy would result in the loss of the greater part of the increase, and this proved to be so in the two subjects examined. Both had a patellectomy performed several years previously and both had no functional disability in everyday life. Clinical examination revealed a thickening in the tendon where the patella had been. There was some quadriceps atrophy on the affected side, especially in the second case, but in spite of this the response to the usual clinical tests of function were normal. There was no limitation of flexion in either case, and on the whole the end-results could be regarded as very satisfactory. But the dynamometer revealed the true state of the extensor efficiency (Table IV). At 60 degrees the power of extension was less than on the normal side. This confirms the quadriceps atrophy because with equal quadriceps the power of extension should be greater in the patellectomized leg at 60 degrees and 90 degrees. Loss of the patella resulted in a greatly reduced power of knee extension in the extended positions, and since these are the positions most important to man's activities it is correct to conclude that the operation makes the knee less efficient than the normal one. This loss of efficiency may not show clinically or be felt by the patient in everyday activities since the quadriceps possesses a large reserve of power, but cases have been reported in which the functional efficiency is obviously below normal.

Applying the results of this study of patellar function to the surgical treatment of conditions involving the patella, it can be said that since patellectomy definitely impairs the efficiency of the extensor apparatus of the knee joint the operation should be avoided when possible. It is indicated in conditions such as severely comminuted fractures and in inflammatory and neoplastic diseases of the bone. It appears to be indicated in osteoarthritis when this is mainly confined to the patellofemoral articulation, for it has been shown in this study that the knee is likely to be more efficient after patellectomy, and good results have been reported by Ludloff, Friberg, Berkheiser, and Zeno and Maróttoli. Whether better results are obtained in simple transverse fractures by removal of the fragments or by the more conservative methods of fixation is still doubtful, since no large comparable series have been reported. But it cannot now be claimed in favor of complete extirpation that function of the knee is thus improved.

With regard to the technique of patellectomy, this work shows that, for greatest efficiency, the quadriceps tendon should be pulled down and sutured to the patellar tendon, as advised by Maróttoli and by Friberg. The reason is that the central tendon, restored by this suture, transmits the pull of the quadriceps more efficiently than do the patellar retinacula. Furthermore, the fibers of the quadri-

ceps muscle are stretched by this procedure and can, therefore, contract more strongly in obedience to the physiological law mentioned earlier. This stretching causes a reduction in the cross-section of the quadriceps which may be permanent. Though it might be thought permanently to limit flexion of the knee it does not in fact do so.[1]

One other point of considerable practical importance is the great tension which the quadriceps can produce in its tendon and which the patella has to transmit. With the knee joint at 60 degrees, a force of extension exceeding 40 kilograms at the ankle was achieved by several subjects. Since the average mechanical disadvantage for the quadriceps in this position is 15.4: 1 the tension in the quadriceps tendon in these cases was more than 600 kilograms. No wonder that the patella is often snapped across the end of the femur by sudden contractions of the quadriceps, and small wonder that it is the most frequently refractured bone in the body (8)! It is obvious that no sutures, however skilfully inserted and however strong, will withstand strains of a fraction of this magnitude, and it follows that weight-bearing movements of the knee after patellectomy or after suture of a fracture should not be commenced until the tissues have had time to heal strongly.

## SUMMARY

1. The patella is a sesamoid bone developed in and lying in the line of the extensor tendon of the knee.

2. Its phylogenetic and ontogenetic development indicate it probably has a function.

3. Experimental work shows that the patella improves the efficiency of knee extension in the more important extended positions of the knee joint by holding the patellar tendon away from the axis and thereby increasing the extending moment of the quadriceps pull.

4. Clinical investigations confirm the experimental findings.

5. Patellectomy is justifiable in patello-femoral osteoarthritis.

6. In the operation of patellectomy the quadriceps tendon should be sutured to the patellar tendon and quadriceps activity much restricted until healing is sound.

[1]Friberg, personal communication.

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# ROENTGEN THERAPY AS AN ADJUNCT IN THE MANAGEMENT OF ACUTE POSTPARTUM MASTITIS

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ROENTGEN treatment of acute postpartum mastitis has been successful in Europe (Goetz, Granzo, Goedel, Hanne, Kautsky, Margraf, Pfalz, Pohl, Steinkamm, Theiss) and in the few clinics from which it has been reported in this country (Elward and Dodek, McIntosh 17, 18). Widespread acceptance of this method of treatment has been hampered by (1) failure to realize that a co-ordinated plan of management of these patients is necessary even when roentgen therapy is given, (2) simultaneous combinations of conflicting forms of treatment, and (3) delay in referring these patients for roentgen therapy until other methods of treatment have failed to relieve the patient.

In January, 1942, a co-operative plan of treatment of acute mastitis was undertaken by the departments of obstetrics and radiology. Since that time, the only breast abscesses which have occurred have been in some of the patients initially treated by other methods at home and subsequently referred for roentgen treatment or in patients treated entirely by methods other than roentgen therapy.

The current report is based upon the methods used and results obtained in treating one hundred patients with roentgen therapy for acute mastitis between January, 1942, and June, 1944. Sixty of these patients developed mastitis while in the hospital on the obstetrical service and 40 patients developed the disease after leaving the hospital. During the same interval there were 15 patients with mastitis who were not referred for roentgen therapy; 9 of these patients having developed the disease in the hospital and 6 having been referred to the hospital for treatment. In the preceding 16 years of the hospital's existence 77 patients have been treated for acute postpartum mastitis, 31 patients having developed the disease in the hospital and 46 patients having been referred to the hospital for treatment.

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The recent increase in incidence of primary involvement, as well as increase in bilateral involvement, from 24 per cent formerly to 37 per cent in the current series, has been the subject of much discussion, investigation, and concern. Much of this increase seems to be related to a decrease in available trained nurses for care and instruction of patients, a shortage of resident and senior staff doctors, a marked increase in birth rate, and difficulties in maintaining and replacing mechanical equipment related to obstetrical practice. Increased interest in the subject as a result of the method of treatment used can be discounted as a factor in the increase in the number of cases recognized in the hospital because the gravity of signs and symptoms in most of the patients were such that they could not be overlooked, nor the diagnosis missed. At most, there were 5 patients whose initial manifestations and subsequent courses were so mild that, under former circumstances, they might have been classified as "one day fever" or "one day fever-breasts." Most of the individuals who developed mastitis after leaving the hospital were referred back for roentgen treatment because of interest in, or acknowledgment of, the method. How many of these patients might have been hospitalized under earlier circumstances for other methods of treatment cannot be estimated. At any rate, only 6 of the 40 had to be admitted either from severity of toxic symptoms, home conditions, or suppuration.

## DIAGNOSIS

The diagnosis of this disease is most accurately made by a combination of subjective symptoms and objective observations. Some patients note pain from cracked or fissured nipples from one to several nursing periods before the onset of mastitis. Then a portion of the breast becomes tender, and fever, aches, and chills occur. Other patients have an explosive onset of their symptoms with high fever, chills, aches, sweats, headache, coryza, and what the patients consider or admit to be a little incidental tenderness of one breast. In the latter group, urine cultures, uterine cultures, chest roentgenograms, and ear, nose, and

throat examinations are sometimes in progress before it is realized that a breast infection could account for all the symptoms.

Objectively, two types of initial infection of the breast are noted. They are differentiated into superficial or interstitial and deep or glandular mastitis. Neither form remains separately identifiable for many hours, so that most patients have a mixed type of involvement by 24 to 36 hours. The superficial type most often arises from infection introduced through cracks or fissures of the nipple and abrasions of the breast surface. When the lymphatics become involved erythema appears over the involved portion of the breast. As the infection spreads the deeper structures of the breast may become indurated. The glandular type of mastitis often results from infection in areas of stasis from incomplete emptying or obstructed milk flow. It is usually limited for several hours to one lobe of the breast where induration and tenderness are noted. Later, as the infection spreads, a superficial erythema develops over the involved area. The ability of these deep or glandular infections to cause necrosis and abscess formation is well known; such complications sometimes occur within 48 hours from onset of symptoms. Unless recognized and effectively treated early, the infection may spread from lobe to lobe until much of the breast becomes involved.

By requiring fever, local tenderness, and erythema as basic criteria for the diagnosis of acute mastitis, we have eliminated engorgement and caking as factors in this series. Other features of the disease which are useful as adjuncts in making the diagnosis are the time of onset, more common unilateral initial involvement, and leucocytosis.

Figure 1 illustrates the time of onset of mastitis in our roentgen treated and other groups. As in other reported series of cases the peak incidence occurred in the second postpartum week, sporadic cases occurred throughout the nursing period, and a minor increase was noted at the time lactation was suppressed. We hesitate to make the diagnosis under the fifth postpartum day although we have seen 3 patients. We have been called to see several other febrile patients who had combinations of engorgement or caking and uterine infection, pyelitis, or respiratory infection. One patient with axillary lymph node tuberculosis was excluded on the second postpartum day because of bilateral matted tender lymph nodes, previous history, and absence of definite symptoms in the breasts themselves.

Nine of the group not given roentgen therapy and 13 of the patients referred for roentgen therapy showed initial bilateral mastitis.

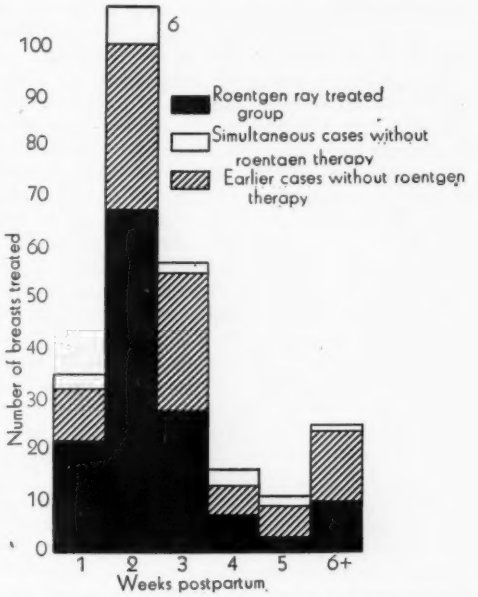


Fig. 1. Shows the time of onset of all the cases of acute postpartum mastitis diagnosed and treated in this hospital and its clinics.

The leucocyte count was above 10,000 in all but 2 of the roentgen treated and 3 of the other patients. The extremes in initial counts were 6,100 to 31,000. The average elevation of the roentgen treated group was 14,900, and in the other groups 14,400.

## TREATMENT

The satisfactory management of these patients requires a co-operative plan among patient, nurse, obstetrician, and radiologist. The following subdivisions discuss most of the factors which make up a plan to insure comfort and speedy recovery for the patient and safety for the infant.

*Roentgen therapy.* The initial dose of roentgen therapy used in this series of patients varied from 40r to 100r and was dependent on the severity of manifestations of the disease and size of the area involved. The most acutely ill patients or those with large areas of involvement were given the small initial dose, while those with milder symptoms and smaller areas of involvement were given the larger initial dose of roentgen rays. The choice of kilovoltage, filtration, and target-skin distance was individualized for each patient. Patients with superficial infection only, or those with small flat breasts with superficial or deep infections, were usually treated at 120 kilovolts,

10 milliamperes, 3 millimeter aluminum filter and 21.5 to 40 centimeter target skin distance. The other patients were treated at 200 kilovolts, 25 milliamperes, 0.5 millimeter copper and 1.0 millimeter aluminum filter and 50 centimeter target skin distance. Changes were made in subsequent treatments from one kilovoltage and filtration to the other if residual manifestations of the disease changed from superficial to deep or deep to superficial. The size of the treated area at the initial treatment was considerably in excess of the size of the involved area. It usually included most of the breast and lymphatic drainage related to the involved area of the breast. Subsequent treatments were usually confined to the smaller involved areas only. The time interval between treatments was usually 24 hours, but in a few patients in whom the initial dose of roentgen rays failed to halt the temperature climb after 8 to 12 hours, an additional treatment of 50r was given the same day with excellent results.

The number of treatments used in this series varied from one to five per breast and averaged 2.3 treatments per breast. The total dosage per breast varied from 40r to 400r and averaged 165r. Indications for more than one treatment are continued fever, residual pain or tenderness in the breast, induration, and elevated white blood count. Erythema is not a safe indication for more treatment since it often increases after the first treatment and may persist for 24 to 72 hours after all other symptoms of active infection have disappeared. In general, if a patient does not show satisfactory response in 36 to 48 hours, during which time two or three roentgen treatments have been given, this form of therapy should be discontinued.

*Nursing.* There have been four instances of infant diarrhea, two of infant stomatitis, and one of infant parotitis noted shortly after the appearance of maternal mastitis in this group of patients. For this reason we prefer that the baby not nurse from the infected breast during the acute phase of the disease. There is usually enough pain associated with nursing from the infected breast so that the infant does not obtain the desired amount of milk with usual ease and is likely to further traumatize the infected area. Infections located in the areolar or periareolar area are a greater contraindication to nursing than are those situated farther out or deeper in the breast. Nursing is usually interrupted from the infected breast for 6 to 18 hours. If the patient does not show marked constitutional reactions, it is safe to continue nursing from the uninvolved breast.

*Pumping the breast.* This procedure is controversial in the literature (Klahn, Moon and Gilbert) both as an individual therapeutic procedure and as an adjunct to other forms of therapy. Its place is limited but essential. It has probably aborted many early cases of mastitis based on stasis from incomplete emptying of the breast during nursing, but the technique of its proper use is so complicated that it often does more harm than good. We delay the use of a breast pump in patients with primary areolar or periareolar infection because of the massaging action which such an area receives during the pumping procedures. When the infection is elsewhere in the breast, pumping every 8 hours is permitted but is not usually prescribed. Regardless of where the infection is, if distention from milk causes discomfort to the patient, a gentle 5 minute pumping will take off enough milk to bring marked relief to the patient. In patients too ill to nurse their babies, the sound breast is pumped at regular nursing periods, and the involved breast only under the above conditions.

*Drying up lactation.* Any infection which cannot be cleared in 48 hours so seriously interferes with the infant feeding routine that function should be terminated in both breasts. When bilateral mastitis occurs, nursing should be terminated unless there is a period of several days between clearing of the infection in one breast and the onset of infection in the other breast. Some of the most stubborn cases of mastitis respond rapidly to treatment when lactation is suppressed.

TABLE I.—RESULTS IN 100 ROENTGEN-RAY TREATED PATIENTS OF THIS SERIES

Onset in hospital

| Duration of symptoms before roentgen treatment | Number breasts | Number cures | Number resistant | Number abscesses | Per cent abscesses |
|---|---|---|---|---|---|
| Less then 24 hours | 72 | 70 | 2* | 0 | 0 |
| 24 to 48 hours | 12 | 12 | 0 | 0 | 0 |
| 48 to 72 hours | 1 | 1 | 0 | 0 | 0 |
| More than 72 hours | 1 | 1 | 0 | 0 | 0 |

Onset after leaving hospital

| Duration of symptoms before roentgen treatment | Number breasts | Number cures | Number resistant | Number abscesses | Per cent abscesses |
|---|---|---|---|---|---|
| Less than 24 hours | 31 | 31 | 0 | 0 | 0 |
| 24 to 48 hours | 13 | 13 | 0 | 0 | 0 |
| 48 to 72 hours | 3 | 3 | 0 | 0 | 0 |
| More than 72 hours | 4 | 2 | 0 | 2 | 50 |

*See Evaluation of Method.

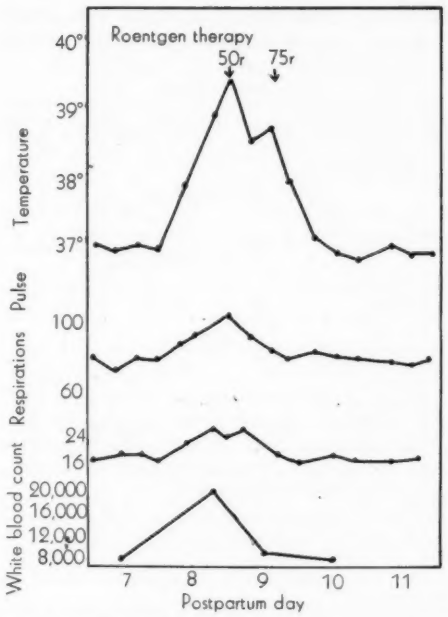


Fig. 2. Illustrates typical changes in temperature, pulse, respiration, and leucocyte count in patients with acute postpartum mastitis treated here with roentgen rays.

*Breast binders.* All of our patients are markedly relieved when support is furnished to the breast to prevent motion of the inflamed area. Heavy binders gently applied are indicated on those patients who will probably resume the nursing function, and heavy binders tightly applied are indicated when lactation is to be suppressed. As soon as the acute phase is over, these binders can be discarded from those patients who are to resume the nursing function.

*Ice packs.* Ice has an immediate numbing effect on the painful area and decreases the blood flow to the involved area with resultant decrease in absorption of toxins into the general circulation. It also decreases the rate of milk secretion and thereby lessens the need for artificial emptying of the breast. When ice bags are used on an infected breast and the patient is nursing from the normal side, the ice should be removed from the patient one-half hour before each nursing because of a transient reflex suppression of lactation in the normal side. The use of ice is limited to the most painful period of the disease which is usually the few hours intervening between application of roentgen rays and the time their effect becomes noticeable.

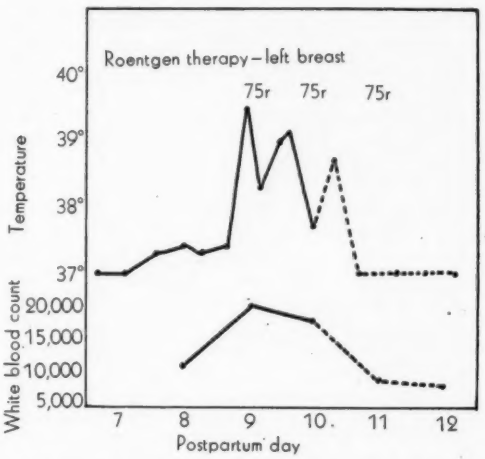


Fig. 3. Illustrates the importance of an elevated leucocyte level in prescribing more treatment when all other signs and symptoms indicate a rapidly clearing mastitis at the junction of the solid and broken lines.

*Heat.* In the early stages of mastitis, local heat makes the patient much more uncomfortable. It apparently increases cicrculation in an already engorged structure and facilitates absorption of toxins into the general body circulation. Later, if suppuration starts heat is more comforting than ice.

*Fluids.* No attempt is made to limit fluid intake during the course of the acute infection, even if the breasts are being dried up at the time. When the infection has subsided, fluids can be limited if lactation is to be suppressed.

*Sedation.* Threshold tolerance for pain is so variable that no routine is maintained in this aspect of treatment. Salicylates are frequently prescribed, and combined with codeine only in extreme situations.

*White blood count.* The course of the white blood count is of considerable significance in evaluating true response to treatment. We prefer a count at the start of treatment and daily thereafter until treatment is stopped. Figure 2 shows the correlation of temperature, pulse, respiration, and white blood count as we have observed them in many of the cases treated with roentgen rays. Figure 3 shows the indication for more treatment at the time of the junction between the solid and broken lines on the basis of the white blood count in the presence of questionable residual breast symptoms. Figure 4 likewise shows the indication for treatment on the basis of the white blood count in the presence of a subclinical mastitis in

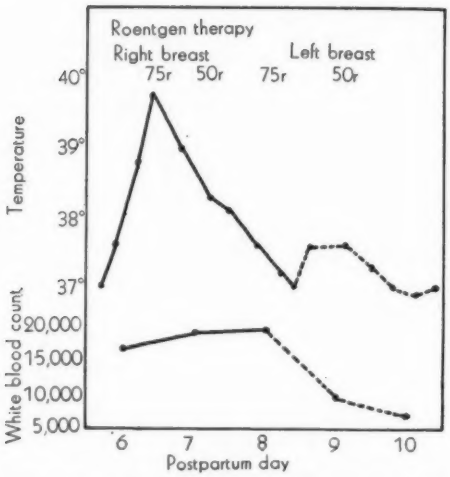


Fig. 4. Similar to Figure 3 but the leucocyte elevation at the junction of the solid and broken line is apparently related to a beginning mastitis in the opposite breast. Prompt treatment of the second breast when signs of mastitis became definite resulted in a comparatively mild course.

the second breast at the time the first breast was completely relieved by roentgen therapy. The second breast rapidly developed clinical signs of infection.

## RESULTS

The results obtained from the use of roentgen rays as an adjunct in the treatment of mastitis in the series of 100 patients in this report are shown in Table I.

The results obtained from the use of other methods of treatment (mainly ice packs and occasionally heat or sulfonamides) on patients who developed mastitis during the same interval as the preceding group are shown in Table II.

TABLE II.—RESULTS OF USE OF ICE PACKS, HEAT OR SULFONAMIDES IN OTHER PATIENTS DURING SAME INTERVAL

Onset in hospital

| Duration of symptoms before any treatment | Number breasts | Number cures | Number abscesses | Per cent abscesses |
|---|---|---|---|---|
| Less than 24 hours | 10 | 10 | 0 | 0 |

Onset after leaving hospital

| Duration of symptoms before any treatment | Number breasts | Number cures | Number abscesses | Per cent abscesses |
|---|---|---|---|---|
| Less than 24 hours | 5 | 2 | 3 | 60 |
| 24 to 48 hours | 1 | 1 | 0 | 0 |
| 48 to 72 hours | 1 | 0 | 1 | 100 |

TABLE III.—RESULTS OF USE OF ICE PACKS, HEAT OR SULFONAMIDES IN MASTITIS PRIOR TO CURRENT SERIES

Onset in hospital

| Duration of symptoms before any treatment | Number breasts | Number cures | Number abscesses | Per cent abscesses |
|---|---|---|---|---|
| Less than 24 hours | 22 | 18 | 4 | 18 |

Onset after leaving hospital

| Duration of symptoms before any treatment | Number breasts | Number cures | Number abscesses | Per cent abscesses |
|---|---|---|---|---|
| Less than 24 hours | 22 | 18 | 4 | 18 |
| 24 to 48 hours | 16 | 12 | 4 | 25 |
| 48 to 72 hours | 4 | 3 | 1 | 25 |
| More than 72 hours | 16 | 9 | 7 | 44 |

Results which were obtained from the use of other methods of treatment (mainly ice packs and occasionally heat or sulfonamides) on patients who developed mastitis prior to the current study are shown in Table III.

Table IV gives a comparison of the preceding results with typical results from the literature.

## EVALUATION OF METHOD

The literature on roentgen treatment of acute postpartum mastitis leads one to believe that striking relief from all symptoms occurs immediately after treatment. We have never noticed this in treating other infections such as furuncles, parotitis, and cellulitis and have not been surprised to find that the same type of interval exists between treatment and effect in this condition. It is granted that a few of our patients have been free from all symptoms two hours after treatment, but in any large series of patients there will be some mild infections which will subside quickly irrespective of treatment. Most of the roentgen treated patients actually do go through some type of crisis 4 to 8 hours after treatment, and thereafter do feel markedly improved. Careful tabulation of the maximum duration of all subjective symptoms and objective findings in the roentgen treated series reveals that the average duration of subjective symptoms is 1.88 days, and objective findings, 2.45 days. In contrast are the figures of the group not treated with roentgen rays in whom suppuration did not occur, with an average of 8 days of subjective symptoms and 10.3 days of objective findings. The group operated upon had subjective symptoms from infection for an average of 44.6 days and objective findings for an average of 47.7 days per patient.

No one knows definitely what reaction takes place in an irradiated infection of this type. We do know that the doses of roentgen rays used are

TABLE IV.—COMPARISON OF RESULTS IN TABLES I, II, AND III WITH THOSE IN LITERATURE

| Author | Year reported | Treatment | Number patients | Number cures | Number abscesses | Per cent abscesses |
|---|---|---|---|---|---|---|
| Theiss | 1935 | Conservative | 135 | 120 | 15 | 11 |
| | | Early roentgen ray | 120 | 118 | 2 | 1.8 |
| Steinkamm | 1936 | Conservative | 47 | 35 | 12 | 25.5 |
| | | Early roentgen ray | 34 | 32 | 2 | 6 |
| Margraf | 1936 | Conservative | 85 | 69 | 16 | 19 |
| | | Early roentgen ray | 65 | 60 | 5 | 8 |
| McIntosh | 1940 | Conservative | 187 | 152 | 35 | 18.7 |
| | | Roentgen ray in 24 hours | 36 | 35 | 1 | 2.7 |
| | | 48 hours | 14 | 6 | 8 | 57.1 |
| McIntosh | 1941 | Conservative | 134 | 112 | 22 | 16.4 |
| | | Roentgen ray in 24 hours | 75 | 74 | 1 | 1.3 |
| | | 48 hours | 59 | 38 | 21 | 35.5 |

infinitesimal as far as ability directly to affect the bacteria themselves (Duggar, Wyckhoff). Experimental evidence indicates that there is a transient hyperemia of microscopic proportion in the affected area (Dyes; Tannenberg and Bayer) that leucocytes are attracted in increased number to the area (Osgood), that minor local chemical changes occur (Lieber; Schoenholz and Hirsch; Shade, Beck, and Reimers), and that the whole process of defense against local infection is speeded (Desjardins).

The prompt recognition and admission of the possibility that there may be patients who will fail to respond to roentgen therapy is important in establishing opinions as to the value of the method. There is also the constant possibility that symptoms of infection elsewhere in the body can be superimposed upon some of those of mastitis and, unless one acknowledges this, he might treat a mastitis beyond actual necessity. One patient was changed from roentgen to sulfadiazine therapy because there had been no local improvement after 3 roentgen treatments in 36 hours and the other breast was developing mastitis. Nursing was stopped at this point. The infection subsided gradually, but there were 2 recurrences of the disease during the next 6 weeks. The first recurrence responded to sulfadiazine, and the last, a milder attack, subsided with ice packs alone. The only unusual finding during the initial attack and recurrences was a white blood count ranging between 6,100 and 6,800 in spite of fever above 104 degrees F. for several days during the first attack, 103 degrees F. in the first recurrence, and 101 degrees F. in the second recurrence. Another patient was similarly changed from roentgen to sulfadiazine therapy because of only moderate improvement in the infected breast and a persistent white blood count elevation. Twelve hours after starting sulfadiazine a severe phlebitis of the legs became obvious, and 18 hours later mastitis developed in the opposite breast. The breast infection subsided without surgical intervention. Finally, a patient who showed good response locally to roentgen therapy continued to have a daily fever as high as 105 degrees F. The white blood count, which dropped to normal with treatment of mastitis, continued to drop afterward to 4,000. A chest roentgenogram and her subsequent course were consistent with atypical virus pneumonia.

Recurrences of mastitis in roentgen treated breasts have been unusual in reported series. One of our patients developed a second mastitis in another area of the breast 10 days after original treatment. One roentgen treatment brought about a cure.

Prophylactic irradiation of breasts with questionable or suspicious signs of mastitis has been recommended (Mueller) but we cannot endorse this procedure. There seems to be no more possibility of protection from such a procedure than from irradiating a foot because it is anticipated that a nail may be run into the foot. Since the action of roentgen-rays is mainly on the inflammatory reaction accompanying an infection, no basis for prophylactic action would appear to exist.

All of the reports agree that there is no alteration in milk flow subsequent to the treatments. Although 3 of our patients noted decrease in milk flow after treatment, this is no more than can be accounted for on the basis of the infection itself, high fever, temporary suppression due to ice packs or increasing parity. Information regarding nursing before and after the treatment discussed in this paper is available on 90 of the 100 patients: 7 never nursed; 14 ceased nursing before any signs of mastitis were present; 45 nursed before and after treatment; 24 were unable to nurse after treatment for the following reasons—(a) 3 refused to nurse after onset of pain, (b) 2 were admitted to the hospital and separated from the baby, (c) 3 had insufficient milk before and after treatment, (d) 3 had insufficient milk after treatment, (e) 2 had severe fissures of the nipples, (f) 11 had severe bilateral infection either simultaneously or in close sequence. Two patients

have gone through subsequent pregnancies and lactation periods without trouble, and a third patient developed bilateral mastitis with two successive pregnancies.

We have made no attempt to make a comparative evaluation of sulfonamides for this condition. Two roentgen resistant infections cleared when patients were placed on sulfadiazine, although one of these patients developed a severe mastitis in the second breast 18 hours after being started on the drug. Another patient had been on sulfadiazine for a week for an ear infection and developed bilateral mastitis while still taking the drug. In 2 other patients started on sulfadiazine 1 and 24 hours after appearance of the first symptoms of mastitis, abscesses necessitated operation 48 and 72 hours later, respectively. We have avoided simultaneous treatment with sulfonamides and roentgen-rays because of unsatisfactory results in other types of acute infections both experimental and clinical here (Sewell, Dowdy, and Vincent) and in the literature (Flocks, Fellows, and Kerr; Kelly and Dowell, 11, 12; Marks; Tchaperoff). When these patients are seen early and there is no question of the extent of the disease, it seems more rational to treat the local area with roentgen-rays than the whole body with chemicals in order to affect a local infection. Sulfonamides have the distinct advantage of availability for use everywhere, while roentgen therapy is limited to more densely populated areas.

We consider any breast infection which has existed for 48 hours or longer before being referred for roentgen therapy as a definite risk for abscess formation. If, by local examination, there is any suggestion of suppuration, we request the referring physician to perform a diagnostic aspiration of the area for pus. If pus is not found, the chance is about 50 per cent of treating the patient without suppuration developing. If pus is found, we give the referring doctor the choice of himself preparing the patient for surgery or having us give one or two preoperative treatments of 150 to 200r each in order to speed localization of pus, facilitate evacuation at operation, and drainage subsequently.

A persistent objection to the roentgen treatment of these patients has been the cost. Referring doctors see a big difference between the cost of application of ice and roentgen therapy. The following summary of charges compares ward rates and private rates for various groups of patients with mastitis treated between January, 1942, and June, 1944. The charges are based on cost of hospitalization on either prolonged initial or readmission basis, operating room and anesthesia fee, and roentgen therapy. These charges do not include the professional fees of attending doctor or surgeons, but do include the radiologist's fee in all cases.

The average cost per infected breast treated during or prolonging patient's postpartum hospitalization period are as follows: Conservative methods—ward rate, $17.22; private rate, $27.50. Roentgen therapy method—ward rate, $9.12; private rate, $19.35.

Average cost per infected breast treated after patient's initial discharge from the hospital but readmitted for treatment including surgical procedures when necessary: Conservative methods—ward rate, $54.00; private rate, $84.50. Roentgen therapy method—ward rate, $26.55; private rate, $45.44.

Excluding the cost of those patients who had to be hospitalized in the preceding group, the average cost of ambulatory treatment would be: Conservative methods—ward rate, doctor's fee; private rate, doctor's fee. Roentgen therapy method—ward rate, $4.60; private rate, $11.50.

## SUMMARY AND CONCLUSIONS

1. Roentgen therapy combined with rational symptomatic treatment of 137 breasts affected by acute postpartum mastitis resulted in 2 abscesses, 1.5 per cent, as compared with 20 per cent abscesses with other methods of treatment in use prior to this series. The 2 abscesses in the roentgen treated group occurred in patients initially treated by other methods and not referred for roentgen therapy until 4 and 7 days after onset of the disease.

2. The duration of subjective symptoms in these patients was reduced from an average of 8 days with methods of treatment other than roentgen therapy to an average of 1.8 days with roentgen therapy.

3. Application of roentgen therapy is so effective in the early stages of this disease that treatment should be started as soon as the diagnosis can be definitely made, regardless of the hour. Delay in starting this treatment decreases chances of recovery without surgery.

4. A co-ordinated plan of management of these patients is necessary in order to secure the best results, and such a plan has been discussed in this paper.

5. Acknowledgement of infections apparently resistant to roentgen therapy is made and management of these patients is suggested.

6. Analysis of patient costs reveals that roentgen therapy is the cheapest form of therapy for acute postpartum mastitis.

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# SUSPENSION OF THE UTERUS USING THE PFANNENSTIEL INCISION

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MALPOSITIONS of the uterus is a subject that has stimulated the imagination and ingenuity of gynecologists and surgeons for centuries. Some appreciation of this statement is forthcoming when we recall that more than 150 original operations and more than 300 mechanical devices have been designed for the correction of these conditions. All of this effort gives unmistakable evidence of the complexity and difficulty which these problems may present.

The multiplicity of procedures has added much to the confusion, especially to the inexperienced. Though many of the operations have been discarded, the subject is still not clear in the minds of a great many. A large group of these operations were designed in that period of gynecological history when it was the consensus that the uterus and other pelvic structures could be supported from "above" without respect to the integrity of the pelvic diaphragms. While this theory upon which many of these operations were based has been obsolete for more than a generation, some of them are still popular wherever surgery is practiced, notwithstanding the shortcomings of these procedures.

It is not strange, therefore, that these older operations, conceived and designed upon an untenable theory, should be found upon close examination to be unsound in physiological, anatomical, and surgical principle. Nor is it surprising that such operations should be subject to serious complications and malfunction of the uterus and other pelvic organs. To be more specific, these operations are represented by the Gilliam, the Olshausen, the Doléris, the Kelly, the Kocher, the Leopold, the Vineberg, and their numerous modifications. Time and space, however, do not permit a detailed discussion of these operations, but these generalizations at least serve to bring into focus the principles which we believe should underlie a suspension operation.

We are aware that gynecologists are reticent to attribute any function to the round ligaments. We believe that normally the round ligaments have the function of training the uterus forward in anteversion and at the same time allow the uterus to rotate back and forth upon its transverse axis (at the level of Mackenrodt's ligaments) to accommodate the mobile demands made upon the uterus by its environment and its functions.

The revival of interest in the Pfannenstiel and other transverse incisions has, during the past years, resulted in a more extensive use of this incision by many surgeons. We believe, however, that its usefulness is still unappreciated, more particularly by those who have not used it. This incision has several advantages and, prominent among them, is its utility in a suspension operation to be described. As an incision, it represents a true gridiron and meets the important surgical requirements of a good incision in that it causes minimal injury to aponeurosis, muscles, nerves, and lymph and blood vessels. It is for these reasons that it heals promptly, leaves a strong abdominal wound, resists infection, and gives the best possible cosmetic result. We have gained the impression furthermore that it is attended with less shock and requires less postoperative analgesia than does the longitudinal incision.

On the contrary, the incision has certain contraindications which should be borne in mind. It is not well adapted to large tumors above 6 or 8 inches in diameter. It is contraindicated in very obese women in whom the pelvic line is often buried very deeply below the surrounding skin. In these women this incision invites infection. Though it is seldom that pelvic surgery is performed in the presence of virulent infection, it probably should not be employed when such infections are known to exist, as the incision does not lend itself well to drainage. It has also been condemned on the ground of being time consuming, but if this disadvantage exists, it is outweighed by the advantages which we have pointed out. We have not found it to be any more time consuming than the closure of the improved longitudinal incision; that is, the opening of both rectus sheaths and subsequent approximation of the muscles and sheaths.

The details of the Pfannenstiel incision[1] have been so well described by others that no further

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[1]Callandar. Surgical Anatomy. P. 287. Philadelphia: W. B. Saunders Co., 1942.

Fig. 1. The instrument is introduced through the internal ring and then opened about 1 centimeter to grasp the round ligament about its midpoint.

description is required here. We do believe, however, that it is important to point out that the sight of election for this incision is through the pelvic line, which is almost always present.

### THE OPERATION

Step 1. The usual Pfannenstiel incision is made and the peritoneum is opened. General inspection of the abdominal cavity is made, and other necessary surgery is performed. The round ligament is then brought up into the abdominal wound by the following maneuvers: The first assistant retracts the right rectus upward and outward with his left hand. The operator makes gentle traction upon the right round ligament to the left to accentuate the exit of the ligament through the internal abdominal ring. With his left hand the operator inserts a long curved hemostat behind the aponeurosis into the internal abdominal ring, which it should enter without appreciable resistance, lateral to the round ligament. The nose of the instrument should be visible through the peritoneum which the hemostat should perforate at or near the ring. The hemostat is now opened about 1 centimeter and the round ligament is grasped about its middle (Fig. 1) and then brought through the peritoneum and the ring, and thence into the abdominal wound where it is caught with an Allis clamp and dropped into the angle of the wound. The left round ligament is brought into the abdominal wound by the same technique except that functions of the first assistant and the operator are reversed. The result is carefully inspected to make sure that no knuckle of peritoneum is brought through, with the danger of subsequent hernia formation.

Step 2. Both round ligament loops are now drawn mesially along the lower aponeurotic leaf until the uterus is brought into the desired position of correction. The position of the loops now determines the position at which the anchor sutures should be set, and these points are marked by small notches in the lower aponeurotic leaf. The loops are dropped back into the angles of the wound. The anchor sutures cannot be set at this stage of the operation as they will interfere with the closure of the peritoneum and rectus muscles.

Step 3. After the peritoneum has been closed and the recti approximated, the round ligaments are again brought to the point which is marked on the aponeurosis. The round ligaments are then sutured to the posterior surface of the aponeurosis with a mattress stitch of nonabsorbable material. The aponeurosis is then approximated, and this continuous suture should go through, but not around, the ligament (Figs. 2, 3). It is important not to remove the Allis clamp until the anchor sutures have been placed, because, if this is

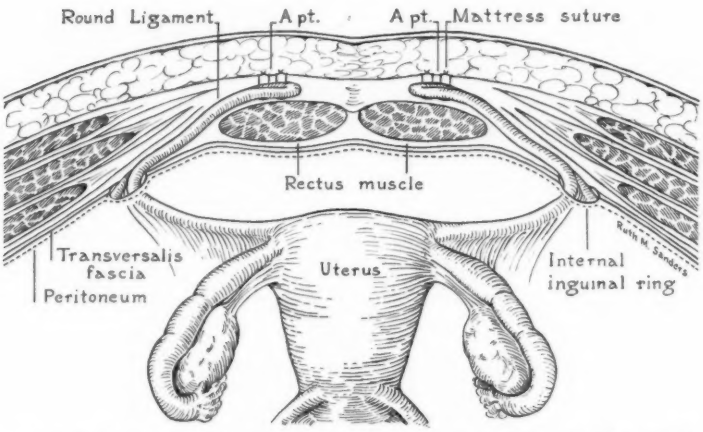


Fig. 2. The final relationship of the round ligament loops to the rectus sheath. *A pt.* is the anchor point for the loops and is determined by the location which gives the best correction.

inadvertently done, the loops will slip back into the abdomen which will have to be reopened to secure them again.

## SUMMARY AND CONCLUSIONS

The pattern of this operation is based upon our understanding of the normal which is in brief that the uterus is supported by Mackenrodt's ligaments, the pelvic diaphragms, and the round ligaments. It is a stable suspension operation which does not interfere with the normal free mobility and functions of the uterus and other pelvic organs. The operation necessitates a minimum of trauma to the viscera and a minimal disturbance of normal anatomical lines and relations (Fig. 4). It eliminates the possibility of complications and handicaps that are known to follow most of the operations still in common use. The futility of suspension operations in descensus without adequate reconstruction of the defective supporting structures of the uterus, bladder, and rectum must be emphasized again.

We have outlined a type of suspension which should produce excellent results, eliminate trauma to peritoneum, and do away with those intraperitoneal pockets which may produce obstruction.

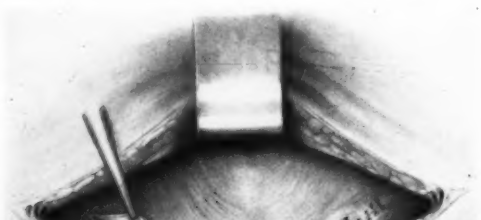

Fig. 3. The round ligaments are sutured to posterior surface of the aponeurosis with a mattress suture and then caught in the continuous suture which closes the aponeurosis. (Some of these closures were done with interrupted sutures in the aponeurosis.)

Fig. 4. Final position of the uterus. There is a minimum of intraperitoneal trauma and no pockets are formed.

We advocate the use of the Pfannenstiel incision for this procedure, and for other gynecological procedures in properly chosen cases. The operation does not contraindicate pregnancy nor make delivery difficult, as several of our patients who have had suspension operations have gone on to normal delivery. By planting the round ligaments under the aponeurosis, we bury the stumps which frequently prove painful and bothersome after their subcutaneous suture.

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# ADDING MORE SAFETY TO GASTROINTESTINAL SUTURES

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SURGEONS are in unanimous agreement that a good suture for the gastrointestinal tract should fulfill at least the following five requirements: (1) hemostasis, a requirement of paramount importance that cannot be overemphasized; (2) impermeability to liquids and gases under moderate pressure from within; (3) isolation, that is, after the repair is finished no part of the mucosa of the suture should be seen; (4) conservation of an adequate lumen for the unobstructed passage of the intestinal contents; and (5) unimpairment of healing, a requirement which is met by avoiding undue traction on the suture line and trauma to the tissues adjacent to the stoma.

Most of the intestinal sutures proposed by various authors for closing the anterior portion of the stoma have not been accepted with equal enthusiasm by surgeons, because of their failure to fulfill completely the five requirements stated. Of all the sutures which have been proposed that of Connell is the one most commonly used at the present time. However, this suture, as performed today and as illustrated and described in textbooks, does not seem to be completely hemostatic and hence does not fulfill adequately the first requirement given. It leaves "free islands" of intestinal wall between the loops of the suture, a serious drawback especially for the abundantly vascularized gastric and jejunal mucosae. This fact is illustrated in the accompanying Figures 1 and 3.

Moreover, these "free islands" created by the Connell suture might also be weak points at which leakage could occur when the intraluminal pressure becomes increased. This statement can be appreciated if we take into consideration that the union of a sutured bowel begins by a deposit of coagulated exudate which results from the trauma inflicted by the needle and by the presence of the suture. Consequently, if the sutures are spaced far apart—and this happens in the Connell suture unless the operator is particularly meticulous—or if the edges are not well approximated, adequate closure of the gastrointestinal wound is not obtained.

To correct the deficiency of the Connell suture and especially to achieve better hemostasis, the following suture for the anterior part of the stoma is proposed, as illustrated in Figures 2, 4, and 5.

From the Department of Anatomy, College of Medicine, University of Illinois.

## TECHNIQUE

Only the technique for the closure of the anterior portion of the stoma will be described in detail; the other steps are mentioned simply to consider the anastomosis adequately.

After the two segments of the alimentary tract, which are about to be anastomosed, are placed in proper apposition by rubber covered clamps, they are united by a continued seroserosal suture of cotton thread. This suture must be placed toward the mesenteric border of the intestine near the clamps, in order to allow enough space for the posterior through-and-through suture after the two apposed visceral organs are opened.

The posterior continuous seroserosal suture starts a little beyond one extremity of the stoma and ends a little past the other extremity, where it is advisable to knot it and so prevent puckering of the anastomosis. Both ends of the suture should be left long with the needle still threaded and laid aside, covered with gauze, to be used later. The opening of the apposed viscera usually is started with a scalpel about ¼ centimeter from the continuous seroserosal suture and finished with a pair of scissors. The length of the opening varies according to the contemplated function of the stoma. The cavities of the organs are aspirated and cleaned. If the mucosa is very redundant, part of it is excised and trimmed. With the cavi-

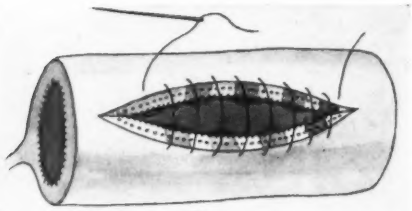

Fig. 1. Sketch showing Connell suture allowing wide "free islands" of mucosa as potential areas of hemorrhage and leakage. Compare with Figures 2 and 4 and notice how "free islands" almost vanish when proposed suture is used.

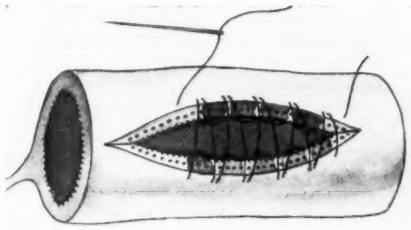

Fig. 2. Sketch showing modified suture obliterating the dangerous "free islands" and thus eliminating the possibility of hemorrhage and leakage. Compare this with Figures 1 and 3.

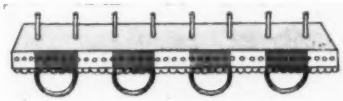

Fig. 3. Schematic presentation of intestinal mucosa and loops of Connell sutures showing the "free islands" (white areas) allowed to exist in this type of suture. Compare this with Figure 4.

Fig. 4. Showing intestinal mucosa with loop of modified suture which almost obliterates completely the "free islands" thus eliminating the dangers of hemorrhage and leakage.

ties of both organs opened, union of the posterior portion of the stoma is effected with a through-and-through continuous suture. Beginning at one extremity, the needle is passed from the mucous surface of one viscus through its wall to its serous surface and from the serous surface of the opposite viscus into the cavity of the latter. The needle comes again to the mucosa of the first organ about ⅓ centimeter in front of the previous suture, and the same maneuver is repeated until the other extremity is reached. If desired, the suture may be knotted from time to time to prevent puckering.

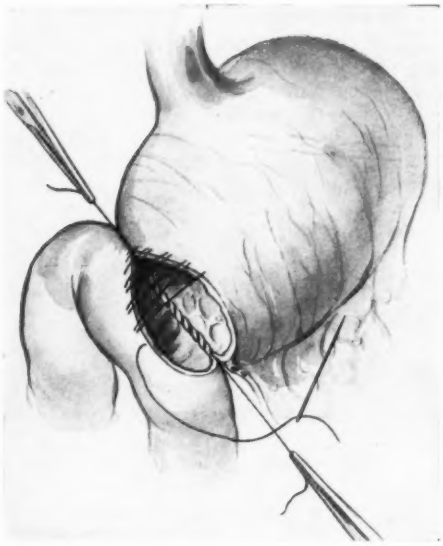

Fig. 5. Showing gastroenteroanastomosis in which modified suture is being used.

As the surgeon reaches the angles of the stoma he should continue carefully, beginning the approximation of the anterior margins of the apposed viscera. To bring the angles of the stoma together the needle is passed from the mucous surface of one viscus to its serous surface, then from the serous surface of the other viscus to its mucous surface, after which the suture is drawn tight and the process is repeated by starting again from the mucosa of the opposite viscus until the angles of the stoma are successfully inverted.

When the angles of the stoma are inverted, the closure of the anterior portion is begun by the use of the proposed modified suture. The same needle that was just used to complete the inversion of the angles of the stoma, threaded with the same thread, after it is made to enter one organ from its serous surface toward its mucous surface, is advanced about ⅓ or ½ centimeter, according to the thickness of the organ. Thereby perforating the mucosa and serosa of the same side, a loop of the suture is formed on the mucosal side. Then the needle is inserted into the serosal side of the opposite organ, perforating the wall and entering its cavity within 1 millimeter of the previous suture at this side. The needle is advanced again at

the mucosal side ⅓ or ½ centimeter, as stated, before it pierces the mucosa and serosa from within outward. Then the cavity again is entered by the needle from the opposite side at a distance of about 1 millimeter from the previous suture. The process is repeated exactly in the same way until the entire intestinal wound is closed.

When the entire circumference of the stoma has been united by this modified through-and-through suture, the catgut thread is tied to its original end at the starting point and cut short. The seroserosal suture, previously laid aside, is now resumed, reinforcing the anastomosis on its anterior aspect and completing the circumference of the wound to its starting point where it is to be tied to its own initial end and cut short. Few interrupted seroserosal sutures, placed at the stomal angles and other points, complete the anastomosis, without overcrowding the stoma with foreign material or jeopardizing its potency with undue infolding.

The accompanying illustrations, Figures 2, 4, and 5, will help to clarify the description as just given and portray the hemostatic effect of such a suture in comparison to that of the commonly used Connell suture, as illustrated in Figures 1 and 3.

SUMMARY

It is assumed that the basic requirements that make a suture of the gastrointestinal tract "safe" are: (1) complete hemostasis; (2) impermeability; (3) isolation; (4) creation of an adequate lumen for the passage of its contents; (5) noninterference with healing. The Connell suture, the most commonly used by the majority of surgeons for the closure of the anterior surface of the stoma, does not fulfill all of these requirements, because it leaves "free islands" in the approximated edges which render the suture not completely hemostatic and leakage-proof.

For the correction of this deficiency, a modification of the Connell suture is proposed and described.

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# ACUTE PEPTIC ULCERS FOLLOWING DISTANT OPERATIONS

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AMONG the various complications of peptic ulcers, perforations and hemorrhage are two which require prompt and often heroic attention. It is generally agreed that in 15 per cent of all cases these complications occur as the initial and only manifestation of the disease (2). Fortunately, acute peptic ulcers with or without hemorrhage or perforation, following operations on other than the upper intestinal tract, are rare and for this reason, perhaps, offer bewilderment to the unsuspecting surgeon. A thorough search of the medical literature of the last 20 years reveals literally hundreds of articles on various aspects of peptic ulcer but only very few that are concerned with an acute onset developing in an otherwise uneventful postoperative convalescence.

In 1925 Silver reported a case of thyrotoxicosis that developed signs and symptoms of gastrointestinal hemorrhage on the 6th postoperative day and died shortly thereafter. A postmortem examination disclosed an acute perforating ulcer of the first portion of the duodenum which had eroded the superior pancreaticoduodenal artery and so produced the fatal hemorrhage. In 1932 Cushing reported 3 cases in which patients died of acute perforation of the upper gastrointestinal tract after what were apparently successful operations on the cerebellum, and on 9 others in which patients showed gastric erosion, gastric malacia, and chronic ulcer both as a result of operation on the brain and otherwise increased intracranial pressure. Because his interest was focused on the diencephalon as a possible parasympathetic center whose disturbance was responsible for the acute ulcers, he carefully reviewed the pertinent literature of the previous hundred years dealing with the neurogenic causes of peptic ulcer and cited a number of reports of similar cases. In 1935 Grant described 2 cases of acute duodenal ulcer following intracranial operations, one of which perforated. The following year Vale and Cameron described the case of a 55 year old man treated for fractures after an automobile accident, who on the 21st day following admission developed severe abdominal pain, nausea, and vomiting as a result of a perforated acute ulcer of the first portion of the duodenum. Finally, in 1940 Penner and Bernheim collected from the literature at least 19 cases of gastrointestinal bleeding and acute ulceration of the stomach and duodenum. To these they added 47 cases of their own that showed both erosions and ulcers of the esophagus, stomach, and duodenum. All of these cases, however, were not postoperative for they also included diabetic acidosis and "other conditions."

In a consecutive series of 1,750 necropsies performed at the Jefferson Medical College Hospital in the last 5 years, there were encountered 5 instances of acute peptic ulcer that occurred following operations on other than the upper gastrointestinal tract. They are reported (1) because it is generally not realized that such ulcers may develop following distant operations on other than the brain and (2) because they again emphasize the importance of routine postmortem examination without which none of these cases would have been diagnosed.

From the Clinical Laboratories, Jefferson Medical College Hospital.

## REPORT OF CASES

CASE 1. A white man 68 years old was admitted to the hospital with a history of intermittent colic-like pains in the right lower quadrant of the abdomen for 2 months and vomiting for 1 month. There were no previous gastrointestinal symptoms. Physical and x-ray examinations disclosed a carcinoma of the ascending colon. Because the patient's physical condition was too poor for an extensive resection at one sitting, a cecostomy was first performed followed in several weeks by a resection of the entire ileocecal region. The latter was performed under spinal anesthesia in 3 hours. The patient tolerated the operation very well and was in good condition upon his return to the ward.

The immediate postoperative convalescence was uneventful. On the 9th day after operation the Wangensteen and nasal tubes were removed and a low residue diet was started. Four days later he said he did not feel so good and in the next 24 hours had several successive black stools in bed, vomited bright red blood three times with a total estimated amount of 2,200 cubic centimeters, became cold, clammy, pale, confused and listless, showed a drop in erythrocytes from a previous normal to 2,200,000 per cubic millimeter and in hemoglobin to 49 per cent, and a progressive decline in blood pressure. In spite of transfusions of blood and plasma he died about 36 hours after the onset of his first symptoms.

Necropsy was performed 3½ hours after death. There was no peritonitis. The stomach was greatly dilated and filled with dark red fluid and clotted blood, and "coffee

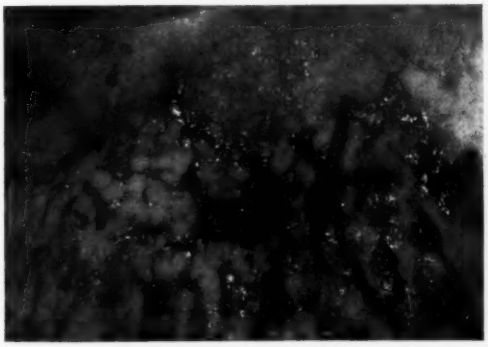

Fig. 1. Case. 1. An acute ulcer of the central portion of the lesser curvature of the stomach. The stump of the eroded vessel cannot be seen in the photograph.

ground" material. The mucosa of the central portion of the lesser curvature disclosed a sharp recent ulcer measuring 1.5 by 1.3 centimeters across and 0.2 centimeters deep (Fig. 1). It was irregular in outline possessing a number of short projections into its lumen and disclosed slight undermining of its edges. Its floor was clean and was formed by the inner surface of the muscle coats. From its central portion there protruded into the crater the stump of an eroded vessel which measured 0.2 centimeter in diameter. Its end was covered with a dark red thrombus. The base of the ulcer was firm and red to gray. Its edges were dark red. In the immediate vicinity the mucosa disclosed 8 satellite erosions and ulcers measuring as much as 0.5 centimeter in diameter and penetrating the mucosa to various levels. Some extended to the submucosa. The mucosa of the body and fundus contained 9 or 10 other similar superficial erosions. The entire ileocecal region was absent and the side to side ileocolostomy was healing well. The suture lines were intact and the ostium was patent. There were several superficial mucosal erosions in the terminal ileum. The mucosa throughout the rest of the small intestine and that of the large intestine was intact. The lumen of both the small and large bowel was filled with black fecal material. There were only a few adhesions around the operative site and as far as could be determined there was no evidence of trauma to any of the structures in the upper abdomen.

The superior mesenteric vein at its entrance into the portal vein contained a recent antemortem thrombus measuring 5 centimeters in length. Nowhere was there any gross evidence of residual or metastatic carcinoma. The lungs were pale pink each weighing about 325 grams. They disclosed no congestion nor did they show any pneumonia. Permission to examine the brain was not granted. There were no other contributory findings. The surgically removed ileocecal portion of the intestine showed a large ulcerating and stenosing carcinoma of the ascending colon with no gross involvement of the draining lymph nodes.

Microscopic sections of the tumor mass in the ascending colon disclosed an ordinary adenocarcinoma. There was no metastasis to the surrounding lymph nodes. Many sections were taken of the large ulcer of the stomach together with almost all of the remaining smaller ulcers and erosions. In addition numerous sections were also made of the entire thickness of the stomach wall 1 centimeter away from the erosions and ulcers particularly where vessels were seen to enter the defects. All sections of the ulcers and erosions

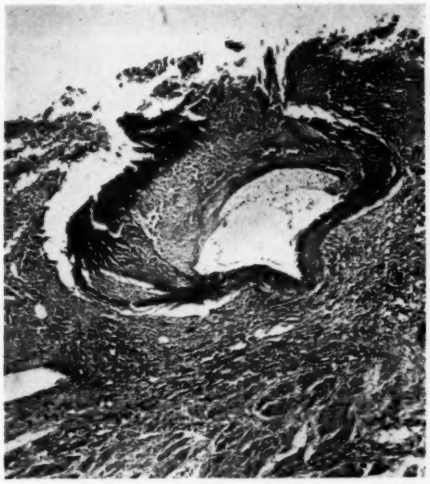

Fig. 2. Case 1. An erosion of an artery in the base of the ulcer shown in Figure 1. Elastic tissue stain, × 35.

showed essentially the same process and differed only in the extent to which the wall was penetrated. Very early only the most superficial portion of the mucosa was defective assuming a small saucer shaped depression. In these there was no surrounding zone of necrosis or inflammation. Where the defects had penetrated to the submuscularis mucosa they were still saucer shaped although the edges were somewhat steeper. Both they and the floor were covered with a layer of fibrin and nuclear fragments intermingled with which were polymorphonuclear leucocytes, plasma cells, and lymphocytes. The submucosa and underlying vessels were entirely normal. The third stage was a penetration of all the coats to the muscle layers. In these the edges of the mucosa were undermined and the entire defect was covered with an inner zone of necrosis, and intermediate zone of polymorphonuclear leucocytes, and nuclear fragments and an outer zone of granulation tissue composed of loose edematous fibroblasts, capillaries and varying numbers of polymorphonuclear leucocytes, plasma cells, and lymphocytes. The inflammatory cells penetrated along the connective tissue between the muscle bundles to and including the serosa. The process was exactly the same in the largest ulcer except that there was more undermining of the mucosa; that about one half of the inner surface of the muscle coats was necrosed, and that there was more inflammation of the surrounding tissue. In the center of this ulcer there was a fairly large artery which showed a complete destruction of that portion of its wall in contact with the ulcer, and thus a communication of its lumen with that of the stomach (Fig. 2). An adjacent vein showed a complete penetration of that portion of the wall facing the ulcer by inflammatory cells and granulation tissue without, however, causing a rupture. The outer portion of both the artery and the vein showed no pathological changes. Of the many vessels examined in sections 1 centimeter away from the erosions and ulcers only 3 showed a slight increase of the subintimal connective tissue reducing the lumen to about two-thirds of its normal caliber in 2 vessels and to one-half its normal caliber in one other. Thrombosis or inflammation was not seen in any of the arteries.

Fig. 3. Case 2. Ulceration of the duodenum. The inner surface is covered with necrotic material followed in turn by zones of polymorphonuclear leucocytes, fibrin, and again inflammatory cells. The serosa is covered with an acute exudate. Hematoxylin and eosin, × 35.

Case 2. A girl 21 years old was admitted with a history of expectoration for 7 years that was associated with a foul odor for 1½ years. In the last 3 months she developed fatigue, weakness, and sharp recurrent pain in the right lower chest. Her appetite was not very good but she tolerated food well and never had any abdominal pain or other symptoms of indigestion. By means of physical, roentgen-ray, and bronchoscopic examination, a diagnosis of bronchiectasis of the right lung was made. Six days after admission a right pneumonectomy was performed under intratrachial cyclopropane anesthesia. Because of very dense fibrous pleural adhesions, the operation was quite difficult and the patient's condition during the procedure was described as "not good."

The following day although her temperature and pulse were slightly elevated it is recorded that she did well. Two days after operation, however, she began to vomit everything she swallowed and 2 days later she complained of nausea and a "lump" in her epigastrium. Because heart sounds were distant, an aspiration of the pericardial cavity yielded pus which on culture showed Streptococcus hemolyticus and nonhemolyticus. On the 6th postoperative day the pericardial cavity was drained after which the patient became confused and then totally irrational. She died 7 days following the pneumonectomy. The erythrocyte count was 4,000,000 per cubic millimeter before the operation; 4,800,000 on the second day after operation, and 3,500,000 just before death. The blood pressure was normal throughout except just prior to the aspiration of the pericardial cavity.

Necropsy was performed 12 hours after death. The peritoneal cavity contained 500 cubic centimeters of bile stained fluid composed of mucus, blood clots, and fibrin. The latter was particularly abundant along the inferior

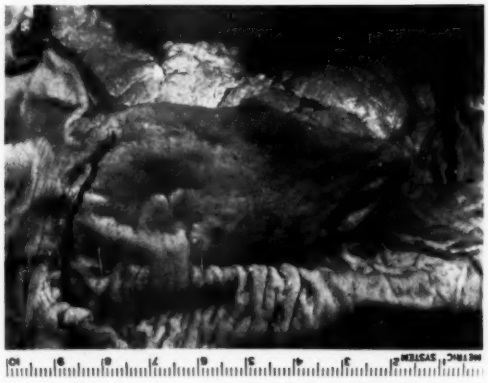

Fig. 4. Case 3. An acute ulcer of the duodenum penetrating into the pancreas.

surface of the liver and around the gall bladder. The first portion of the duodenum just distal to the pylorus contained a mirror defect of the entire anterior and posterior wall each 6 centimeters long and 2.5 centimeters wide. The edges of the perforated wall were clear cut, sharp, covered with an exudate, not indurated, and composed of all the layers of the wall in their normal anatomical arrangement. The mucosa of the stomach and of the remainder of the small intestine and the large intestine was normal. The serosal surfaces of the gut were adherent to each other by mucoid material.

The right lung was absent. The corresponding pleural cavity was reduced in size and the surfaces were covered with a thick fibrinopurulent exudate. The left lung was emphysematous and showed no bronchiectasis. The pericardial cavity was obliterated by a thick fibrinopurulent exudate. The heart was otherwise normal. The mediastinal structures appeared undisturbed. Permission to examine the head was not granted. The surgically removed lung showed extensive bronchiectasis.

Microscopic sections of the edges of the duodenal ulcers disclosed a complete penetration of the entire wall (Fig. 3). The edges were sloping and were covered by an inner zone of necrotic material followed by a layer of polymorphonuclear leucocytes and plasma cells. External to this there was a sharply defined zone of fibrin in which there were only a few inflammatory cells and nuclear fragments. Beyond this area the tissue was somewhat edematous and contained scattered polymorphonuclear leucocytes and plasma cells. The serosa was covered with a thin layer of exudate consisting of fibrin and various cells of inflammatory origin. The vessels in the duodenal wall were normal. Only the very superficial portion of the pancreas was necrotic. The lungs showed congestion, edema, and terminal pneumonia. The pericardium was covered with an exudate of fibrin, polymorphonuclear leucocytes, and round cells. There were no other contributory findings.

Case 3. A boy 17 years old was admitted with a history of pain in the upper chest, and numbness and tingling of both legs of 4 weeks' duration. Gradually increasing weakness developed in the legs until 2 weeks before admission when they became completely paralyzed. There was swelling of the bladder and inability to void. His appetite was fair and there was no history of belching, epigastric distress, or tarry or clay colored stools. Physical examination disclosed spastic paralysis of both legs, a flat abdomen, a few

hot water bottle burns of the skin over the lower abdomen, and superficial ulcers over the bony prominences of the legs and pelvis. A diagnosis of spinal cord tumor was made and 2 days later a laminectomy from the second to the fifth dorsal vertebra was performed under gas and ether anesthesia. Although the immediate postoperative course of the patient was good his condition rapidly deteriorated and he died 14 days after the operation. Just before death his temperature was 96 degrees F., pulse 120 per minute, and respirations 28 per minute. During his stay in the hospital 4 erythrocyte counts varied from 3,400,000 to 4,000,000; the hemoglobin from 61 per cent to 70 per cent, and the blood pressure from 80 to 100 millimeters of mercury systolic and 40 to 65 millimeters diastolic.

Necropsy was performed 2½ hours after death. The body was emaciated and there were superficial ulcers of the skin of the abdomen, sacrum, gluteal regions, thighs, and heels. The posterior wall of the duodenum 2 centimeters from the pylorus contained a punched out recent oval ulcer that measured 0.5 by 0.7 centimeter across and 0.5 centimeter deep (Fig. 4). The edges were finely irregular and undermined for distances of 0.1 to 0.2 centimeter. The base was granular, hemorrhagic, and showed no fibrosis. Most of it appeared to be composed of the muscle coats but along the left border there was a complete perforation of the entire wall into the underlying pancreas that measured 1 by 0.6 centimeter. The pancreatic tissue was superficially brown and necrotic. The superior pancreaticoduodenal artery was found within the substance of the pancreas 0.5 centimeter beneath the base of the ulcer. Its external diameter was 0.2 centimeter and its lumen 0.05 centimeter across. The latter contained a red thrombus for a distance of 2.5 centimeters but showed no other gross abnormalities. The rest of the gastrointestinal tract was entirely normal.

There was no infection of the operative site. Below the level of the surgical incision from the fourth dorsal to the eighth dorsal vertebra there was a soft mushy, gray fungating tumor mass filling the spinal canal and involving the surrounding bone. The brain showed marked congestion of the pia arachnoid vessels but on coronal sections which included the brain stem did not disclose other abnormalities. The remaining organs showed no contributory pathological changes.

Microscopically there was a sudden and complete interruption of the mucosa of the duodenum with penetration of all the coats to the surface of the pancreas (Fig. 5). The mucosal edge of the ulcer was covered with a slight amount of necrotic material, lymphocytes, plasma cells, and polymorphonuclear leucocytes. The latter extended into the mucosa for varying distances. The surface of the undermined mucosa together with the edges of the submucosa, muscle coats, and serosa were covered with an external layer of necrotic material and fibrin in which there were only scattered polymorphonuclear leucocytes and nuclear fragments. Beyond this there was a zone composed almost entirely of polymorphonuclear leucocytes next to which there was a broad band of granulation tissue. The latter was composed of a background of loose edematous connective tissue which contained thin and thick walled capillaries and varying numbers of polymorphonuclear leucocytes, lymphocytes, and plasma cells. This granulation tissue covered but only superficially penetrated the pancreas. Sections through the grossly visible area of perforation disclosed an intact pancreatic surface overlaid with only a thin layer of similar granulation tissue. The superior pancreaticoduodenal artery showed no histopathological change. It was filled with well preserved erythrocytes but showed no ante mortem thrombus.

CASE 4. A white man 57 years old was admitted with a history of cough with expectoration of 6 ounces of sputum daily for one year and "asthma" for 9 months. He had no gastrointestinal symptoms but did lose 40 pounds in weight in 5 months. Physical, roentgen-ray, and bronchoscopic examinations disclosed an abscess of the lower lobe of the left lung. Following several bronchoscopic drainages his temperature gradually came to normal. Two months after admission the abscess was drained externally through the chest wall under local anesthesia. During the operation a large vein was severed from which he bled "freely." Hemorrhage was controlled by pressure and the cavity was packed with sponges. Following a blood transfusion he was returned to the ward in good condition. Three days later the packing was gradually removed and gauze was inserted into the cavity. In 2 more days this was replaced with drains but 3 hours later the cavity was again packed because of bleeding. The next day when the packs were removed there was a sudden gush of blood from the cavity accompanied by hemoptysis, cyanosis, collapse and death.

Fig. 5. Case 3. An undermined and collapsed mucosa. The floor and base of the ulcer are covered on the inner surface with necrotic material and fibrin followed by a zone of polymorphonuclear leucocytes and beyond this by granulation tissue. Hematoxylin and eosin, × 35.

Necropsy was performed 3 hours after death. The cavity in the lower portion of the left lung was filled with a blood soaked gauze and its surface was ragged. The remainder of the left pleural cavity was obliterated with dense fibrous adhesions. The bronchi of the entire left lung and those of the upper lobe of the right lung showed marked cystic dilatations that were filled with a black fluid possessing a foul odor. The stomach was dilated and contained food remnants stained with blood. The gastric mucosa disclosed scattered petechial hemorrhages along the lesser curvature. Directly upon the pyloric sphincter there was a small ulcer possessing sharp margins and hyperemic sloping walls. It measured 0.4 centimeter in diameter. Immediately beyond the pyloric sphincter the duodenum disclosed a "chronic healed" ulcer measuring 0.5 centimeter in diameter and showing a smooth gray base. The rest of

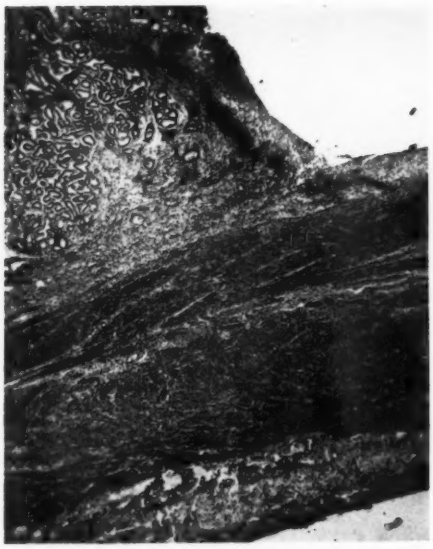

Fig. 6. Case 5. An ulcer of the duodenum covered on the inner surface by polymorphonuclear leucocytes and followed by a zone of fibrin mixed with nuclear fragments and beyond this recent granulation tissue. The latter extends between the muscle bundles to include the serosa. Hematoxylin and eosin, × 35.

the intestinal tract showed congestion but no other abnormalities.

Unfortunately, microscopic sections were not made of the gastric or duodenal ulcers nor was the stomach or duodenum saved. Histologic sections of the lungs disclosed anthracosilicosis and bronchiectasis.

Case 5. A white women 51 years old was admitted to the hospital with a history of constant generalized abdominal pain accompanied by nausea and vomiting and bleeding from the rectum, all of 5 weeks' duration. She had been constipated for a few months and for the last 2 years was said to have had gall-bladder trouble because she belched gas. Eight weeks before admission she was studied for peptic ulcer at another hospital but none was found. Physical examination disclosed a greatly distended tense abdomen; a large intra-abdominal mass extending from the pelvis half way to the umbilicus; ascites, and large hemorrhoids. Four days after admission a peritoneoscopy revealed carcinoma of the ovaries with generalized abdominal metastasis. There were no subsequent notes in the history until 10 days after peritoneoscopy at which time it was stated that the patient was moribund. She died in coma on the twelfth postoperative day. Six days after peritoneoscopy her erythrocyte count dropped from a previous normal to 3,000,000 per cubic millimeter and the hemoglobin from normal to 52 per cent. The blood pressure until 4 days after operation averaged 150 millimeters of mercury systolic and 100 millimeters diastolic. The next reading was 2 days before death at which time it was so low that it could not be read.

Necropsy was performed 1 hour after death. There was a moderate degree of jaundice. To the right and just inferior to the umbilicus there was a recent surgical incision 2 centimeters long. There was considerable hemorrhagic extravasation into the right rectus muscle over a diameter of 7 centimeters. Immediately external to the peritoneum there was a blood clot 4 centimeters in diameter and 1 centimeter thick. This was continuous, by way of the incision, with a large intraperitoneal clot which covered both the bowel and the pelvic organs. The peritoneal cavity contained in addition about 8000 cubic centimeters of dark sanguineous fluid. The serosal surfaces were studded with tumor nodules. Each ovary was replaced with a partly solid and partly cystic tumor mass. The left one measured 10 centimeters in diameter and the right one 4 centimeters. There were many tumor nodules in the liver and some in the lungs and pleura. The gall bladder and bile ducts were normal. The lungs showed only slight congestion and edema. The brain was not examined.

The first portion of the duodenum immediately distal to the pyloric ring contained a superficial punched out ulcer measuring 1 by 0.5 centimeter across and 0.2 centimeter deep. The edges were sloping. The floor was gray and clean. The base was formed by the muscle layers. It was firm and indurated. The mucosa of the rest of the gastrointestinal tract was normal and nowhere did it contain scars or chronic ulcers. The lumen contained no blood.

Microscopic sections of the duodenal ulcer showed a sudden and complete interruption of the mucosa, submusculous mucosa, and submucosa (Fig. 6). The edges were sloping. Both they and the entire bed of the ulcer were covered on the internal surface by a layer of polymorphonuclear leucocytes followed by a narrow band of similar cells mixed with fibrin and nuclear fragments. Beyond this there was a zone of granulation tissue composed of a background of edematous fibroblasts containing only a few capillaries and sprinkled with varying numbers of polymorphonuclear leucocytes, lymphocytes, and plasma cells. The muscle coats were not eroded but they were diffusely infiltrated with a mixture of similar inflammatory cells. The serosa was greatly thickened and replaced with granulation tissue similar to that already described. The arteries showed no histopathologic changes. The lungs showed congestion, edema, and terminal pneumonia. The tumor was a primary adenocarcinoma of the ovary. There were no other relevant findings.

Pathologically there is no question that the ulcers in each of the 5 cases presented here were both ante mortem and acute and furthermore that each was of such an age as to be compatible with an onset dating from the time of operation. Clinically too, although the entire absence of any previous gastrointestinal symptoms in the first 4 cases is not absolute proof that the ulcers were not present prior to operation, it is as good evidence as one can obtain. This contention is further strengthened by the fact that 2 of the patients were 17 and 18 years of age, at which time peptic ulcers are very uncommon. The presence of vague abdominal distress for 2 years in the fifth patient can hardly be related to the duodenal ulcer, first, because as late as 8 weeks before admission to the hospital there was no roentgen-ray evidence of ulceration and, second, the microscopic appearance of the ulcer, namely, its superficial nature, the polymorphonuclear cell reaction and the entire absence of fibrosis bespeak of a

duration in days or at the most a few weeks rather than months or years. There were furthermore no scars to indicate previous ulceration. All her symptoms, on the other hand, are compatible with those resulting from an ovarian carcinoma.

In considering the cause or causes of the ulcers in these cases one is at once confronted with the cause or causes of any acute peptic ulcer, and these have been adequately discussed in the literature from time immemorial. Since the many theories have been recently summarized by Cushing, Harkins, Venderahe, Moon, and others, they will not be reiterated here. A very few pertinent comments, however, do appear to be in order.

Because these patients were all operated upon, shock, as a causative agent must first be considered, for in the opinion of Moon, and Penner and Bernheim this phenomenon decidedly plays a rôle in the formation of some peptic ulcers. Unfortunately, an unequivocal statement as to its presence or absence in these cases cannot be made, for the history records are sadly lacking in the single best criterion for shock, namely hemoconcentration. Judging from the operative and postoperative record, however, it is quite unlikely that it played any part in the formation of the ulcers in Case 1, for this patient withstood operation excellently and his convalescence, until the hemorrhage supervened, was entirely normal. Operative shock may have played a rôle in Case 2 for the condition of this patient was "not good" during the operation, and in Case 3 the patient was obviously a "poor surgical risk" even before the operation. Although the operations in Cases 4 and 5 were performed under local anesthesia, this procedure plus the subsequent hemorrhages might have been a contributing factor in the etiology.

Very little can be said about neurogenic factors for in only 1 case was the brain examined. In none of the cases, however, was there any gross evidence of trauma to the vagal or splanchnic nerves, although in Case 2 the patient had a total pneumonectomy, and there may have been some imperceptible damage to these structures as they passed through the mediastinum. In the others there was no mechanical interference with the nerves for the operative sites were remote. Local vascular changes were apparently not a factor for in none of the cases was there thrombosis or sclerosis of the vessel walls even within the ulcer beds. In Case 1 the vessels surrounding the ulcers likewise showed no appreciable changes.

The similarity between the surgical procedure in Case 1 and that used in producing peptic ulcers in dogs by McMaster is so striking that it cannot be passed over without comment. In 20 dogs he performed a simple jejunocolostomy and left undisturbed the portion of the gut between the anastomosis. Acute, subacute, or chronic peptic ulcers developed in 13 dogs, or 65 per cent. In 3 dogs there was spontaneous perforations and peritonitis. In another group of 11 dogs a jejunocolostomy was also performed, but the intervening portion of bowels was resected. Only 2 of these dogs, or 18 per cent, developed peptic ulcers. In none of the dogs was the upper abdomen touched or trauamatized in any way. The author stated that the mechanism involved in the formation of the ulcers was not divulged. In Case 1 several weeks passed between the time of the anastomosis and the resection of the short circuited loop. Whether this procedure had anything to do with the formation of the gastric ulcers is of course not known, but the similarity between this case and the experiments on the dogs just referred to is most interesting.

SUMMARY

A review of the literature discloses very few reports on acute peptic ulcers following operation on other than the upper gastrointestinal tract. Five cases are presented here. One of these patients died from hemorrhage following erosion of an artery in the stomach wall. The remaining 4 ulcers were in the duodenum. One had perforated and produced peritonitis; another penetrated into the head of the pancreas and 2 were limited by the muscle coats. The causes of the ulcers were not apparent.

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# THE INTERNAL EPICONDYLAR EPIPHYSIS AND ELBOW INJURIES

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FRACTURE dislocation of the elbow in children with inclusion of the internal humeral epicondyle into the joint is not a frequent injury. It is not as rare, however, as was formerly believed. The injury is of extreme importance since the full significance of the pathology is not always appreciated. The dislocation is easily diagnosed, but the displacement of the internal epicondyle into the joint is often unrecognized; the dislocation is reduced but the epicondyle remains within the joint. As a result the child may be doomed to a markedly restricted painful range of motion in the elbow. Since these patients are usually treated first by the general practitioner, camp doctor, or interne, it is highly important that they suspect and look for a displacement of the internal humeral epicondyle in every case of elbow dislocation in children. If a correct diagnosis is made early and the patient treated properly, a well functioning elbow with practically complete and painless motion will usually be insured.

Clinical examination gives some indication of the injury present. A dislocation is obvious and is easily recognized. The normal prominence of the internal humeral epicondyle should be looked for and its absence noted. Comparison should be made with the opposite normal elbow. The presence of localized tenderness over the region of the epicondyle may be significant. Detailed roentgenograms in various views are essential to a correct diagnosis. Fluoroscopic examination alone is inadequate for recognition of the displaced ossicle.

In early cases, the dislocation and displacement of the epicondyle into the joint are both easily reduced by the closed method described in my previous reports. Clinical experience has shown that the method is so important in order to obtain a good result that a review of its description would not be amiss. Its mechanism depends upon the anatomical fact that the internal humeral epicondyle gives origin to a group of muscles by a conjoined tendon. These muscles are the pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum sublimis (humeral head), and the flexor carpi ulnaris (humeral head). By their action these muscles pronate the forearm, flex the wrist and fingers, and aid in flexing the elbow. It is evident, therefore, that if these movements are reversed, marked tension will be applied through these muscles to their point of origin, the epicondyle. With the epicondyle lying free within

From the Northington General Hospital.

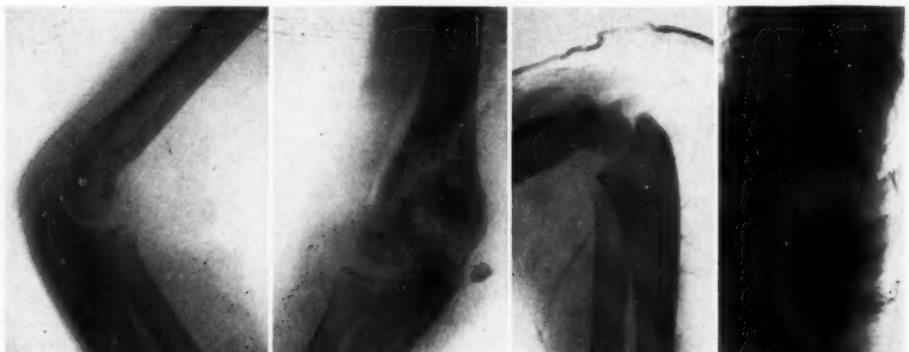

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Fig. 1. Case 1. a, July 24, 1939, separation of internal epicondylar epiphysis with mild downward, mesial and anterior displacement. b, August 7, 1939, slight improvement with elbow in acute flexion.

a b

Fig. 2. Case 2. a, May 31, 1939, posterior and lateral dislocation of right elbow without separation of epicondyle. b, June 29, 1939, twenty-nine days after closed reduction. Note bony proliferation from external condyle of humerus along lateral aspect of joint.

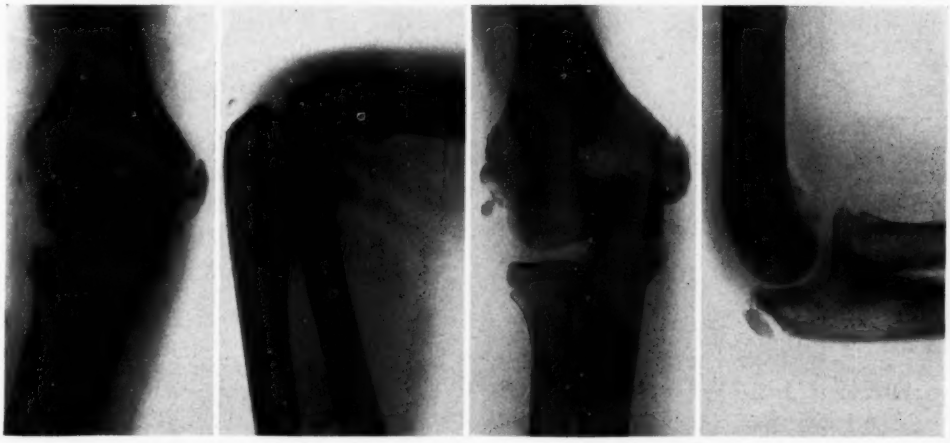

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Fig. 3. Case 2. a, 5 months after injury. Note fragmentation at external humeral condyle as well as increased bone production from internal epicondyle. b, April 28, 1941, 23 months after injury. Note further fragmentation at external humeral condyle and increased bone production from internal epicondyle. Joint appears normal and function is complete.

the joint such tension upon it should dislodge it from the joint. The forearm, is therefore, supinated and the elbow, wrist, and fingers are extended. At the same time the forearm is gently abducted in order to increase the gap between the trochlea and the ulna, thus allowing the epicondyle a free route of exit from the joint. In every early case in which the author employed this maneuver the reduction was easy and complete. It is important to note that no force is required to effect the reduction. In late cases, however, where adhesions have already formed to bind the displaced epicondyle in the joint, open reduction will be necessary. The possibility of some resultant loss of motion is great in these latter cases. Hence the importance of early diagnosis and treatment. In all of the cases in my series except one reduction has been successfully carried out by the closed method. This latter patient was first seen 3 weeks after the reduction of the dislocation and is considered a late case. The enclosure of the internal epicondyle in the joint apparently was

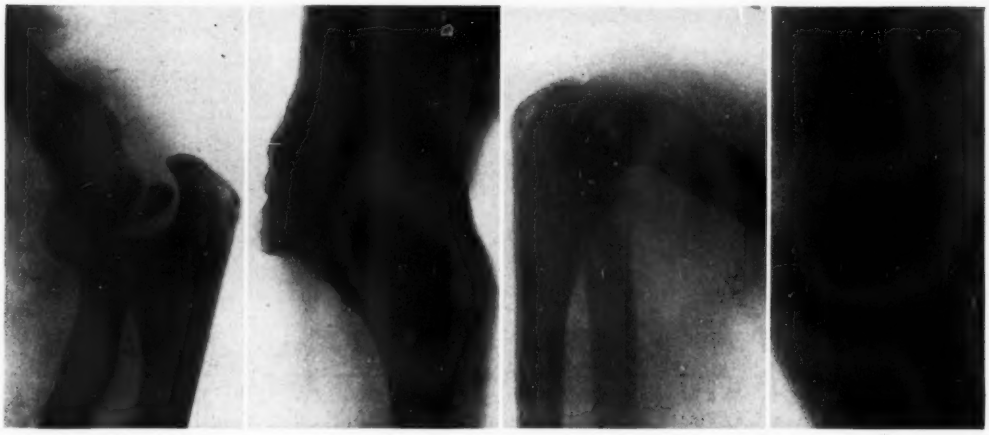

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Fig. 4. Case 3. a, November 17, 1941, posterior and lateral dislocation of elbow with intra-articular interposition of epitrochlea. b, Following closed reduction with good reposition of epicondyle.

not recognized originally. Open reduction was required to remove the epicondyle from the joint, since it was too late even to attempt closed reduction.

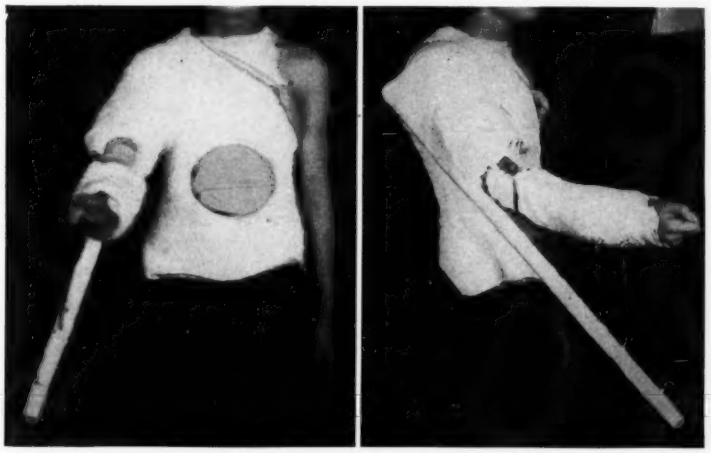
The center of ossification of the internal humeral epicondyle appears at about the age of 5 years and fuses at about the age of 18 years. During this time there is always the possibility that the epicondyle may become avulsed, generally by indirect trauma. The medial epicondyle gives attachment to the ulnar collateral ligament as well as to the superficial flexor muscles of the forearm. Excessive tension on these structures with the elbow in extreme valgus position may avulse the epicondyle or rupture the internal lateral ligament. Indirect violence such as a fall on the outstretched hand with the elbow extended is the history usually obtained. In some of my cases, however, there was a history of direct trauma with a definite fall on the elbow. The degree of pathology varies with the severity of trauma. In the least serious cases the medial epicondyle is only slightly separated. One such case is included in this series. When the trauma is more severe the epicondylar epiphysis may be pulled down to below the articular level of the elbow by flexor muscle pull. The internal lateral ligament and joint capsule may be strained or torn. With greater valgus strain, it is possible for the elbow to open momentarily on its medial aspect so that the epicondyle becomes wedged in the joint between the trochlea and the sigmoid fossa of the ulna. Actually there is no dislocation of the elbow. Such cases have been described by Watson-Jones. In the author's cases in which x-ray films revealed similar wedging of the epicondyle, he has always obtained a history of definite dislocation which was reduced without replacing the epicondyle. The resultant x-ray films are similar to those of Watson-Jones. When no attempt has been made to reduce the dislocation, the roentgenograms reveal the dislocation as well as the epicondyle in the joint. The dislocation is generally lateral and posterior.

In these severe cases with elbow dislocation, the ulnar nerve may be stretched or actually carried into the joint with the displaced epicondylar epiphysis. In 1 case previously reported patient had a definite ulnar nerve paralysis which required open operation for neurolysis and anterior transposition of the nerve subsequent to successful closed reduction of the fracture dislocation. Ulnar nerve function was completely restored. In a second case previously reported there was presented a median nerve disturbance which recovered completely following closed reduction. In the cases to be described patients were devoid of any nerve involvement.

The epiphyseal plate connecting the internal epicondyle to the humerus is generally considered to be the weak link on the medial aspect of the elbow. Ordinarily a severe trauma will cause a disruption at this point. It is possible in some of the severe cases, however, to have a complete dislocation of the elbow without any displacement of the epicondyle. The extreme valgus tension on the inner aspect of the elbow in such a case produces a rupture of the ulnar collateral ligament

a b

Fig. 5. Case 4. a, Complete separation of epitrochlea with displacement into elbow joint. Unrecognized at time of injury 3 weeks previously. b, 26 days following open reduction.



a b

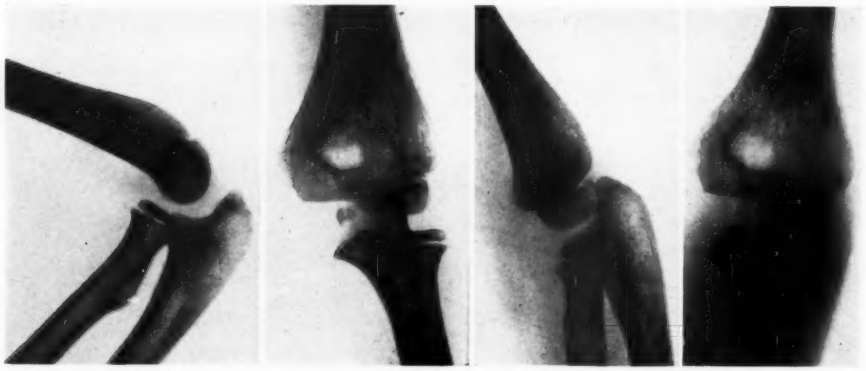
Fig. 6. Case 4. Plaster-of-Paris shoulder spica with extension piece for traction. Hinges incorporated at elbow for motion.

without disturbing the attachment of the epicondyle to the humerus. One such case is included in this series.

CASE 1. A colored boy of 9 years injured his left elbow during a fall on July 24, 1939. He was admitted to Sydenham Hospital where x-ray films revealed a mild separation of the internal epicondylar epiphysis with mesial, anterior, and downward displacement. This case illustrates the simplest type of pathology. The elbow was immobilized in acute flexion with pronation of the forearm for 3 weeks. After only 2 weeks of physical therapy, motion of the elbow was almost complete. The patient failed to return for further therapy, however.

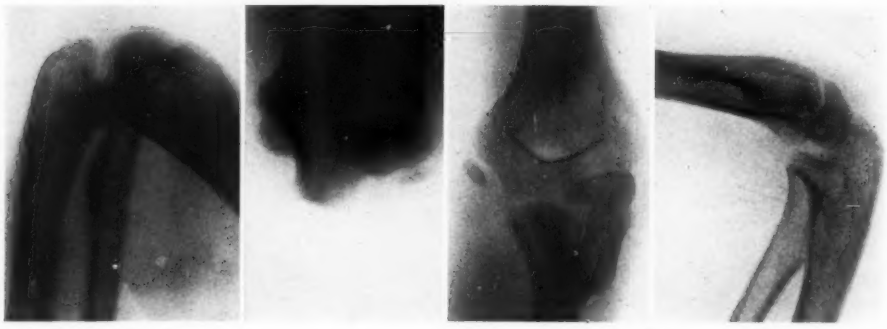
Case 2. A 10 year old colored boy fell and injured his right elbow on May 31, 1939. He was brought to the emergency room at Sydenham Hospital where clinical examination revealed an uncomplicated dislocation of the elbow with lateral and posterior displacement. All of the epiphyses appeared to be in normal position. In this case the ulnar collateral ligament was vulnerable whereas the internal epicondyle remained attached to the humerus. Reduction was obtained under general anesthesia, and the elbow was immobilized in flexion for 2 weeks. Physical therapy was instituted and the patient obtained practically a complete range of motion from 30 degrees to 175 degrees with normal pronation and supination.

The roentgenograms dated June 29, 1939, almost 1 month after injury, reveal bony proliferation from the external condyle distally along the course of the external lateral ligament. This is a common finding in elbow dislocations and was present in both of my earlier cases. The



a b

Fig. 7. Case 5. a, Anteroposterior and lateral x-ray films following closed reduction of dislocation of elbow. Note suspicious oval shadow in lateral view overlying olecranon process within the joint. b, With the elbow in greater extension, the internal humeral epicondyle is easily observed within the elbow joint.



a b

Fig. 8. Case 5. a, Epitrochlear epiphysis in normal position following closed reduction; b, 26 days after closed reduction. Firm fibrous union of epicondylar epiphysis is present clinically.

later x-ray films, however, reveal fragmentation in the region of the external condyle as well as bony proliferation from the internal epicondylar epiphysis. This condition has never been previously observed, nor has the author been able to find any record of such a finding in the literature. These changes evidently do not interfere with joint motion.

CASE 3. A colored boy, 16 years old, fell on his left elbow while playing basketball on November 17, 1941. He presented clinical and x-ray evidence of posterior and lateral dislocation of the elbow with inclusion of the separated internal humeral epicondyle into the joint. Complete reduction was obtained by the closed maneuver, and the arm was immobilized in a Velpeau dressing. The patient failed to reappear for over a month, and elbow motion was definitely restricted. Physical therapy was immediately instituted and after three treatments elbow motion was possible from 75 degrees to 120 degrees. Pronation and supination were complete. The patient again disappeared. His failure to co-operate deprived us of the opportunity of giving him a complete, functioning elbow. It is probable, however, that he obtained this with normal activity.

CASE 4. A girl, 12 years old, was first seen in the dispensary at the Hospital for Joint Diseases on August 11, 1938. Three weeks previously she had tripped over a tent rope at camp and had struck her right elbow against the ground. X-ray films at camp had revealed a dislocation of the elbow which was reduced. Since the elbow remained "frozen," she was brought to the city for further study.

Examination revealed a painful, enlarged elbow, fixed at 90 degrees; neither flexion nor extension was possible. Pronation and supination were somewhat restricted. Roentgenograms revealed a complete separation of the epitrochlea with displacement into the joint. In view of the lapse of time since the injury was sustained, it did not seem feasible to attempt closed reduction. Open operation was therefore performed on August 20. The epicondyle was found firmly bound down in the sigmoid fossa by scar tissue, and it was evident that closed reduction at this late stage could never have been successful. The epicondyle was gently freed and removed from the joint with its muscles. It was then sutured to the periosteum and internal intermuscular septum just above the internal condyle of the humerus.

In view of the length of time that the epicondyle remained in the joint with its damage to the articular cartilage, it was feared that subsequent motion would be impaired. Even when the ossicle was removed on the operating table, the joint could not be carried through a normal arc. Despite every means postoperatively, elbow joint motion was only mildly improved. Physical therapy was first employed. A basswood gutter splint was then applied with gradual traction in order to increase elbow extension. A two-sectioned turnbuckle plaster-of-Paris cast with hinges at the elbow was applied from the upper arm to the palm. A two-sectioned plaster-of-Paris shoulder spica was also applied with hinges at the elbow, and an extension piece from the upper arm posteriorly. Hook screws were inserted into the forearm portion of the plaster, as well as into the extension piece, and heavy rubber bands were applied between them for traction. Despite all these devices, only temporary improvement in joint motion was obtained and this could not be retained. Finally on March 22, x-ray films revealed narrowing of the joint space and it was evident that a normal range of motion was impossible. When last seen on April 19, the elbow could be flexed to 80 degrees and extended to 105 degrees. The failure originally to recognize the epicondyle in the joint and to reduce it early, produced intra-articular changes which precluded satisfactory recovery of elbow motion.

CASE 5. A 10 year old boy fell on his left elbow while at camp on July 13, 1941. There was immediate deformity of the elbow which reduced itself spontaneously as the arm was being placed in a sling by the nurse. He was seen by me within an hour. Examination revealed marked tenderness over the internal epicondyle and as the forearm was gently abducted on the upper arm, the elbow redislocated. It was easily reduced. These findings indicated that we were either dealing with a rupture of the internal lateral ligament of the elbow or with a complete avulsion of the internal humeral epicondyle. Roentgenograms taken at Fairview Hospital appeared to be negative on casual inspection. More careful observation, however, revealed a faintly visible oval shadow superimposed on the olecranon in the lateral view. Because of the marked tenderness over the internal epicondylar region, it was decided to take additional films with the elbow in greater extension. These films confirmed my suspicion and clearly revealed the internal epicondyle displaced within the joint. Under general anesthesia the displaced epicondyle was reduced out of the joint by the closed maneuver described. The elbow was immobilized in flexion and pronation, since this position relaxes the involved muscles and avoids further tension on the epicondyle. The awareness of the possibility of a separation of the internal epicondyle with its inclusion into the joint, in cases of elbow dislocation, spared this boy the fate of the previous case. He obtained a complete range of arm motion at the elbow, except for extension which was restricted less than 5 degrees.

## EVALUATION OF STUDY

Avulsion of the internal humeral epicondyle may be simple or may accompany elbow dislocation. Conversely, dislocation of the elbow may occur alone or be accompanied by a separation of the internal humeral epicondyle. In those cases of dislocation in which the epicondyle becomes displaced within the joint it is highly important that the entire pathology be recognized early and treated without delay. Complete reduction can be obtained in those cases that are treated early by the closed method described. The maximum length of time following injury in which closed reduction may be successful cannot be stated with accuracy. All of the patients in the author's series in which the dislocations were successfully reduced by the closed method were treated within 24 hours after injury. All of them obtained well functioning painless elbows. In the 1 patient who came to open reduction the condition was not accurately diagnosed until 3 weeks after injury. It was too late then to attempt a closed reduction. The relatively poor result obtained in this case emphasizes the extreme importance of early accurate diagnosis and treatment.

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# REPARATIVE PLASTIC SURGERY OF SECONDARY CLEFT LIP AND NASAL DEFORMITIES

EDWARD S. LAMONT, M.D., Hollywood, California

THE stigma of a harelip facies may remain following the initial surgery. Though the latter has been adequate, the deformity may be unavoidable because of inherent defects present both in the lip and nose. With this in mind, a definite plan must be outlined before any operative work is begun and such a plan must cover a span of years (Fig. 1). When secondary repair is considered then the method and the time should be planned when the primary closure is carried out.

The nasal deformity as well as that of the lip identifies the harelip patient. Unless the lip is grossly too long or too tight complicating secondary surgical repair, a reasonable reconstruction may be expected. However, unless the nose too is reconstructed the final picture will be found wanting. The surgeon must weigh the future when proceeding with a primary repair and, when possible, avoid external incisions on the nose. Tissue may be readjusted to allow for a reasonable result with the thought that the procedure may be adequately completed at some later time (9).

## PLANNING RECONSTRUCTION OF THE PRIMARY HARELIP

The plan must include the necessity and timing of any future surgery either of the lip itself or of the deformed nose. If the defect is associated with a cleft palate and the latter is continued anteriorly including the premaxilla, then the technique must be further modified (7). Time and later orthodontia will do much to approximate even wide alveolar clefts. Forceful wiring of the maxilla will often result in irreparable malformation and loss of teeth (4, 14). Occasionally, in primary repair, a wire may be introduced between the two separated halves of the maxilla entering it high on either side and making certain that it is not too tight. It is applied in especially wide clefts and allowed to remain 3 to 6 weeks.

Many pitfalls are offered by the double harelip, especially one with a prominent or a floating premaxilla. A carefully planned operation with undermining and advancement of the cheek after it is freed from the alveolar process of the maxilla will result in reasonable occlusion (2). When the premaxilla has been sacrificed at primary closure, the result is usually unhappy: the upper lip is short, tight, and markedly retruded.

Much discussion has accrued whether the skin of the prolabium is part of the lip or columella. Brown and McDowell (3) have pointed out that the skin borrowed from the prolabium to create the columella in cases of bilateral harelip usually grows hair and so it would appear to be part of the lip.

The initial closure should seek to gain a symmetrical nose with nostrils and a columella that will lend themselves to future surgery and a lip that is neither too short, long, or tight.

A prominent deformity that may occur with double harelip is a short columella. To overcome this defect, cartilage may be implanted at the primary operation so as to stretch the columella. At the time of secondary repair more cartilage is often inserted, as a strut running from the nasal spine to the tip. In those cases in which the lack of columella is such that it may not be remedied by stretching, then a small rectangular flap is turned from the center of the philtrum at its juncture with the columella and slid upward to join the latter.

## PRINCIPLES IN THE TECHNIQUE OF PRIMARY REPAIR

Regardless of the method of procedure, definite accomplishments are desired at the time of primary closure. Brown and McDowell (3) have succinctly expressed these principles. To gain: (1) a pleasing alar direction and level, (2) an intact nostril floor, (3) a symmetrical tip, (4) a straight columella, (5) the upper lip prominent in advance of the lower lip and a full vermilion border, (6) if possible a cupid's bow upper lip and the suggestion of a philtrum.

These accomplishments are not easily acquired, but unless they are considered they rarely occur spontaneously. In conjunction with careful preoperative planning, the surgeon must be prepared to make his surgical method elastic to meet the problems as they arise at the operating table.

From the Division of Plastic Surgery, Cedars of Lebanon Hospital, Hollywood, California.

Presented in abridged form in conjunction with colored surgical motion pictures at the Santa Barbara County Medical Association, May, 1944.

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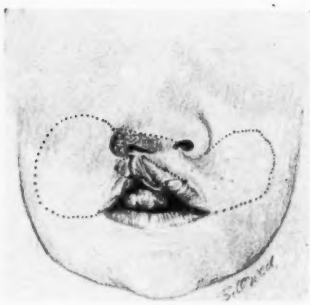

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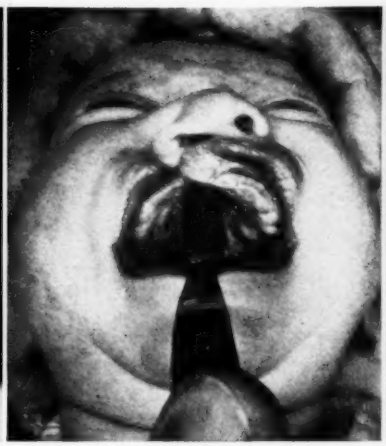

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Fig. 1. Primary harelip and cleft palate repair. a, The flattened nostril, the misplaced vermilion border, and the flaring short side are well depicted. b, The area to be undermined and the points to be approximated are demonstrated. The lower lateral cartilage is undermined both on its anterior and posterior surfaces to allow it to slide into position. c, The flaring prolabium on the affected side is seen. d, The associated cleft palate with a prealveolar cleft complicates the case. e, Photograph 3½ years following repair of the palate, lip, and nose.

*Preoperative study.* Photographs are taken of the child both for study and record. Front view, profile, and nasal triangle shots are important to gauge the amount of deformity. When there is an associated cleft palate, a camera is used with the lens at F40 to gain a closer focal distance.

*Calibration and marking.* The projected lines of incision are marked with a 3 per cent gentian violet solution (U.S.P.). The points to be approximated are carefully measured with calipers so as to obtain a lip that is neither too long nor too tight (Figs. 17, 18, 19).

When the nasal floor requires reconstruction, then sufficient tissue is allotted from the affected side, turned upward, and sewn into position.

The measurements, planning, and judgment are more difficult than the surgery. As little tissue as possible should be sacrificed. Compensation must be made for contracture and growth; often a reasonable result at the operating table appears quite different and possibly disappointing several years later.

*Undermining.* Not only should the whole cheek on the affected short side be undermined away from the alveolar process of the maxilla but so too should most of the cheek on the opposite side (Figs. 15, 16).

Through the gingival margin on the affected side the whole lateral crus of the lower lateral cartilage is meticulously undermined on both its

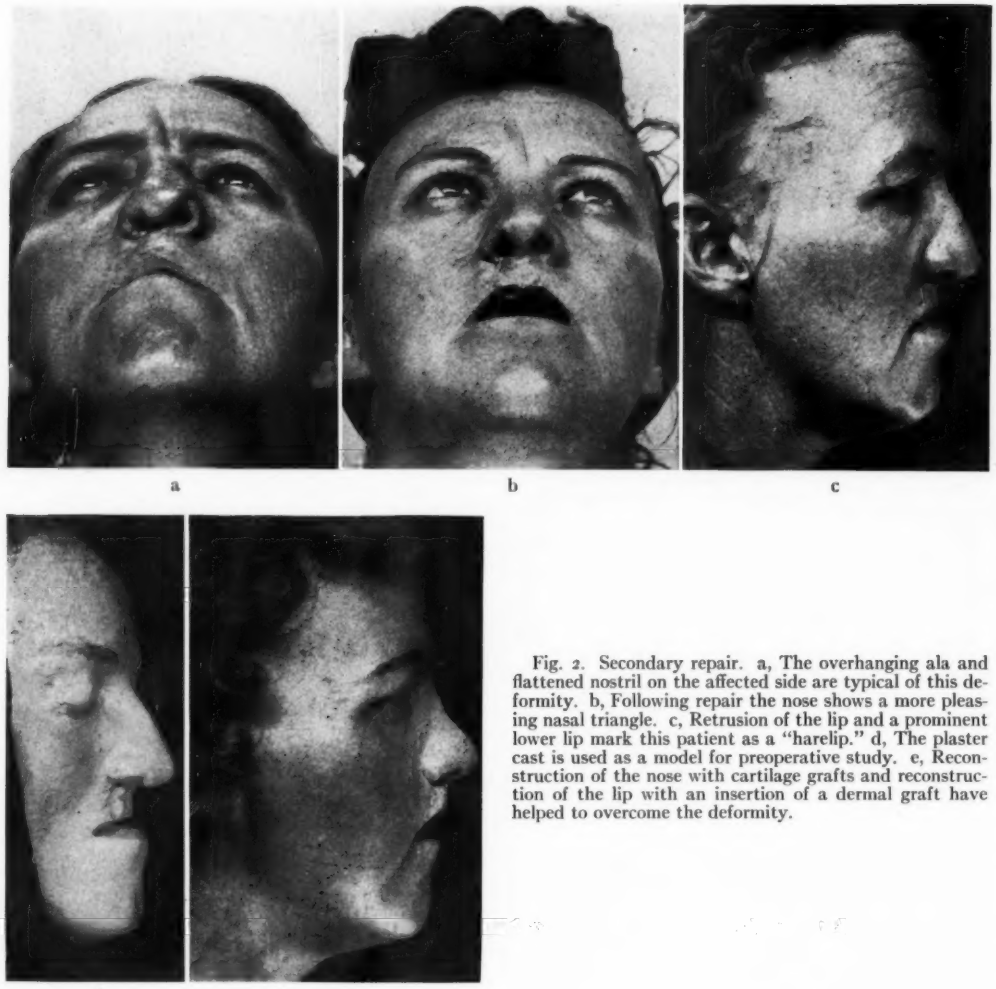



Fig. 2. Secondary repair. a, The overhanging ala and flattened nostril on the affected side are typical of this deformity. b, Following repair the nose shows a more pleasing nasal triangle. c, Retrusion of the lip and a prominent lower lip mark this patient as a "harelip." d, The plaster cast is used as a model for preoperative study. e, Reconstruction of the nose with cartilage grafts and reconstruction of the lip with an insertion of a dermal graft have helped to overcome the deformity.

anterior and posterior surfaces. The undermining anteriorly is high and includes the lower aspect of the upper lateral cartilages, especially on the affected side and should extend past the midline (Fig. 4). There is a definite distortion of the lower lateral cartilage present and, unless it is freed and allowed to slide, the contour of the nostril will remain distorted and buckled at an angle when an attempt is made to bring the affected nostril up to position.

The angle of the ala should be overcorrected. Allowance must be made for contracture and growth. Several mattress sutures are passed through the skin, cartilage, and nasal lining, after the lower lateral cartilage has been undermined. This fixes the distorted cartilage to its new position and helps to avoid bleeding and hematoma.

*Sutures.* Fine white silk is employed to approximate the muscles, for it is believed that silk is stronger than catgut, results in less induration, and allows for earlier symmetrical movement of the whole orbicularis oris.

To avoid the telltale suture marks on the lip, the skin is approximated with a subcuticular silk

a b c

Fig. 3. Illustrating the surgical method in repair of secondary lip deformities. a, The old scar is followed to incise the lip. Relaxing incisions (after J. B. Brown) may be used along the alveolar margin to gain tissue. b, The necessary tissue has been excised and readjusted. c, The mucous membrane has been approximated.

a b c

Fig. 4. Primary repair. a, The fullness on the short side must be utilized to gain a symmetrical lip. b, Reconstruction of the nostril is a prime requisite in harelip repair. The lines of incision and area of undermining are demonstrated. c, Photograph showing the result which was secured following surgery.

suture and the latter is removed in a week or 10 days.

### RECONSTRUCTION OF SECONDARY DEFORMITIES

*Preoperative study.* A plaster mask is taken of the face from which meticulous measurements are made both of the lip and nose. When required, the nasal deformity may be reconstructed with modeling clay so as to gain a more exact plan of the surgical approach. The photographs taken of the front view, profiles and triangle of the nose are conjointly helpful (Fig. 2). When cartilage implants are required, their measurements may be taken from the plaster cast and modeled to fit the deformity.

Deformities confronted in secondary repair of a harelip are the following:

1. The upper lip is short and tight resulting in malocclusion of the teeth. This is usually associated with a protruding overhanging lower lip. A cleft prealveolar process or a surgically absent premaxilla may cause further complication in the picture.

2. The lip may be long and narrow.

3. The vermilion border may be asymmetrical, notched, and partly extending into the upper lip proper.

4. Wide suture marks producing a telltale ladder deformity across the lip.

5. The nasal ala on the affected side is low,

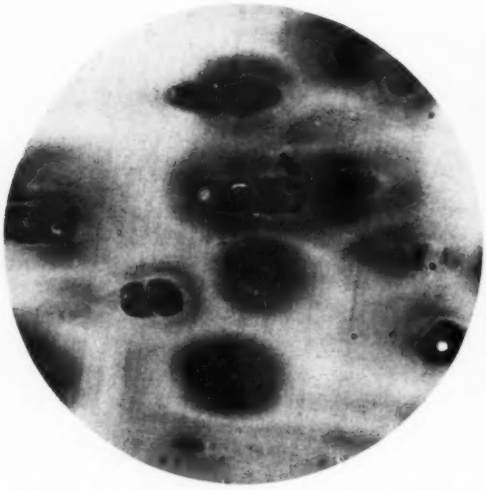
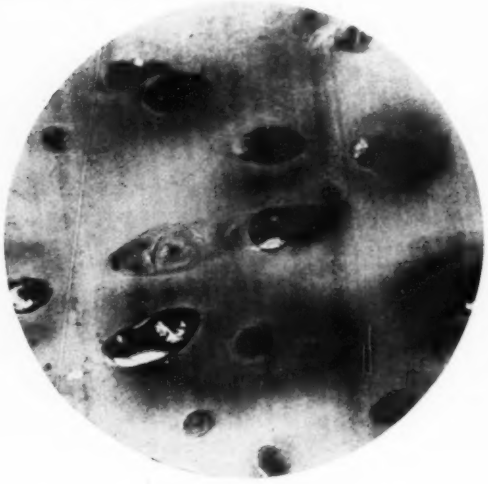


Fig. 5. Necrocartilage fixed directly in Bouin's solution. × 120. This photomicrograph reveals well preserved cartilage with the cells and nuclei appearing normal. In a few places the cells are vacuolated. The matrix immediately around the cells is deeply blue stained, but elsewhere it is pink.

Fig. 6. Necrocartilage placed beneath anterior abdominal wall 1 week, then removed, and fixed in Bouin's solution. × 120. Cells in center are large and blue stained, in places, vacuolated. Nuclei are prominent. Matrix shows usual light and dark blue. At periphery tissue is diffusely pink stained; moderate dissolution of cartilage cells.

flattened, and enters the cheek at a right angle rather than a curve. The opposite nostril is usually flaring.

6. The upper lateral cartilage on the affected side is flattened and there is a flare of the nasal lining into the vestibule.



a

b

Fig. 7. a, Necrocartilage placed in anterior abdominal wall 6 months, then removed and fixed in Bouin's solution. The cartilage is well preserved. The nuclei are distinct. In some places the cells are vacuolated. At the periphery the stain is pink and there is moderate dissolution of the nuclei and cells. b, Necrocartilage refrigerated in merthiolate-saline solution 1:4 for 6 months, then fixed in Bouin's solution. × 120. This presents almost an identical microscopic picture throughout, as the cartilage stored in the abdominal wall (Fig. 7a).

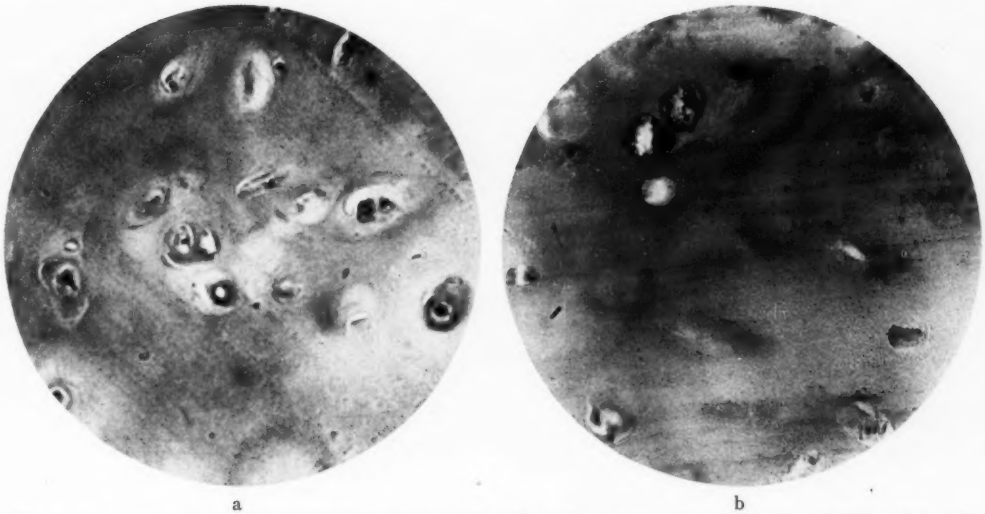


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Fig. 8. a, Autogenous cartilage stored in the abdominal wall 9 months, then removed and fixed in Bouin's solution. Histological comparison reveals this cartilage to appear not much different than necrocartilage treated identically. While most cellular and nuclear outlines are clear, there is a moderate dissolution of cellular elements at the periphery. Surrounding the cartilage is abundance of scar tissue. b, Autogenous cartilage refrigerated in merthiolate-saline solution 9 months, then fixed in Bouin's solution. × 120. Again histological appearance is similar to necrocartilage treated identically. At periphery is a moderate dissolution of cells and matrix is diffusely pink stained.

7. The columella may be short, malformed, or disappearing.

Many of these deformities are unavoidable and must be surgically ignored until the appropriate time for their repair. Procedures which are momentarily spectacular may produce a defective end-result (20).

*Surgery.* The anesthetic is usually local com-

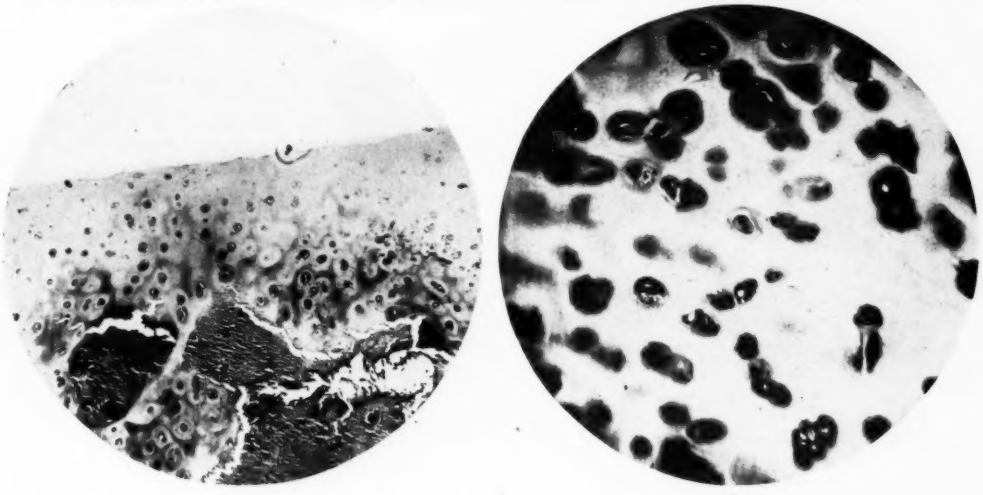

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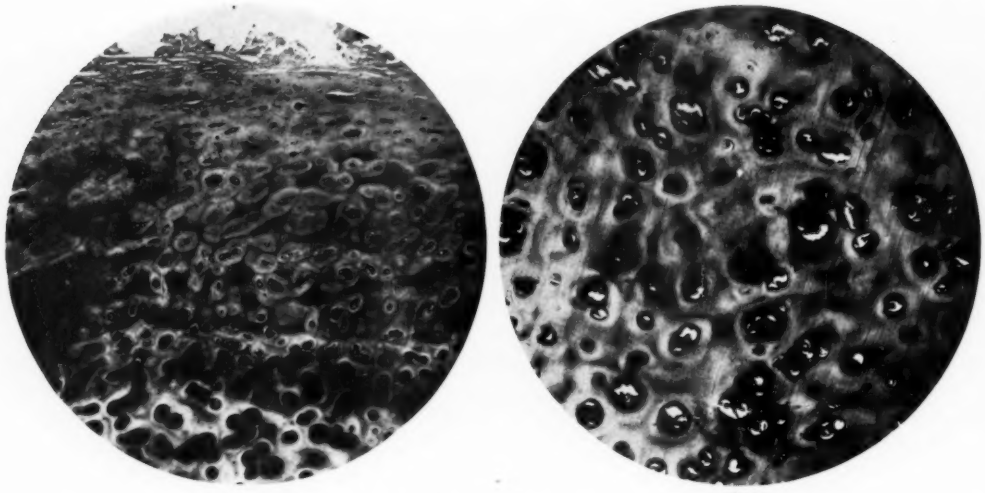
Fig. 9. a, b, Necrocartilage stored in the anterior abdominal wall 2½ years, then removed and fixed in Bouin's solution. Low and high magnification. The cells at the center are reasonably well preserved. The matrix is mainly pink stained. There is an area of focal necrosis in the center.



a b

Fig. 10. a, Low and b, × 120, necrocartilage refrigerated in merthiolate saline solution 1:4 for 2½ years. This specimen is fairly well preserved compared to the previous one. The matrix stains lavender and closely resembles histologically the fresh necrocartilage, which is illustrated in Figure 5.

bining nerve block and infiltration. When general anesthesia is necessary, intratracheal is preferred. The operation may be performed in one or two stages, the nasal reconstruction usually first.

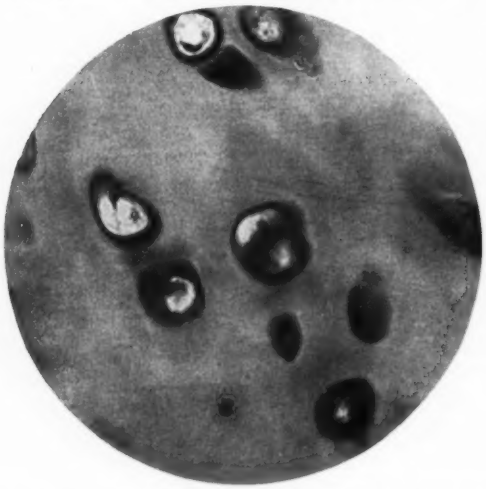


Fig. 11. Autogenous cartilage stored in the anterior abdominal wall 14 years, then removed and fixed in Bouin's solution. The cartilage presents a striking alteration from the normal. There are irregular areas of degeneration characterized by loss of nuclear and cellular structures and a diffuse pink cast to the matrix. In many ways it closely resembles the necrocartilage stored in the abdominal wall for 2½ years.

The peculiar deformity of the nose, especially the nasal triangle, as well as the lip defect calls attention to the harelip patient. A complete rhinoplastic operation is therefore carried out with special attention paid to the tip. The lower lateral cartilages are dissected free. On the affected side, the nostril is usually smaller so the lower lateral cartilage is severed at the arch, the lateral crus completely undermined and allowed to slide. Often a section of cartilage taken from the opposite ala is inserted within this gap. On the unaffected side a similar procedure is done, but here the required amount of cartilage is removed to create less flare and a smaller nostril. The cartilage of the unaffected nostril may be severed more laterally with the remaining medial wing then bent toward the opposite nostril to gain support.

The lower lateral cartilages are dissected free without removing nasal lining. When there is an overhanging nostril or a notch in the ala, the lining is undermined down to the edge of the ala and adjusted to approximate the new position and shape of the lower lateral cartilages.

### THE USE OF NECROCARTILAGE

Few harelip noses are reconstructed that do not require cartilaginous struts either on the dorsum, in the columella, at the columellar-philtrum juncture and occasionally along the alar margins (6,

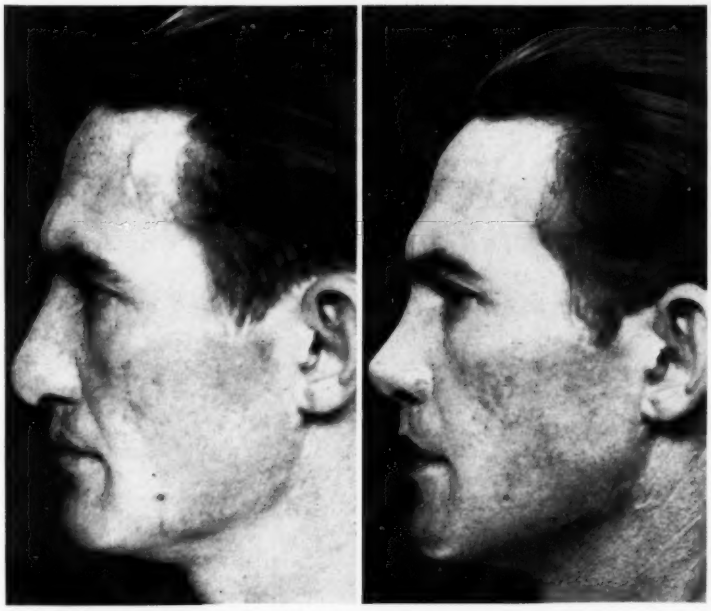


Fig. 12. Secondary harelip and nasal repair. a, left, Overhanging flattened ala with a notched lip and vermilion border. b, Complete rhino-osteoplasty and reconstruction of the lip.

18, 19, 21) (Fig. 14). We have been using rib necrocartilage, fixed first in 4 per cent formalin then refrigerated in merthiolate solution (17).

Experimental work in grafting a whole ear necrocartilage (cadaver) has been continued with rib necrocartilage implanted intranasally (11, 12, 13). To follow the histopathological course of the grafted specimens, portions of the same cartilage were implanted in pockets beneath the anterior abdominal wall (15, 22). Then in intervals after the first week, month, 6 months, 12 months, and 30 months, sections were removed for microscopic study (Figs. 5 through 10). Concurrently, other pieces of the same rib necrocartilage were continued on in merthiolate saline solution and examined for comparison after the same time in-

a b c

Fig. 13. Illustrating the Eastlander-Abbe flap. a, A full thickness triangular section of lower lip with the left inferior labial artery attached is dissected free. b, An incision is made through the upper lip and the pedicle with its artery attached is turned into position. c, The lower lip is closed and the wound edges of the upper lip are approximated to the pedicle. Two to 3 weeks subsequently the inferior labial artery is severed at which time the pedicle which was turned into position has gained total circulation from its new residence.

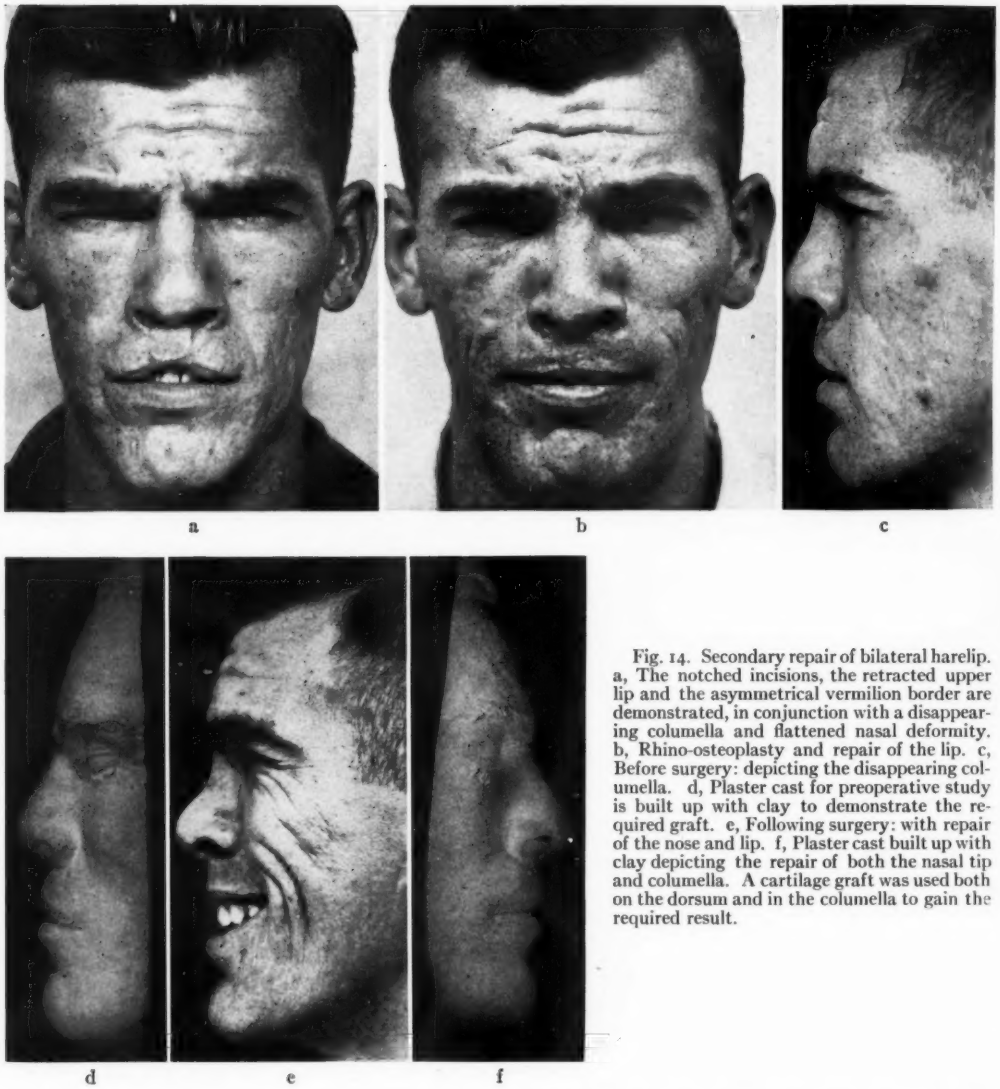



Fig. 14. Secondary repair of bilateral harelip. a, The notched incisions, the retracted upper lip and the asymmetrical vermilion border are demonstrated, in conjunction with a disappearing columella and flattened nasal deformity. b, Rhino-osteoplasty and repair of the lip. c, Before surgery: depicting the disappearing columella. d, Plaster cast for preoperative study is built up with clay to demonstrate the required graft. e, Following surgery: with repair of the nose and lip. f, Plaster cast built up with clay depicting the repair of both the nasal tip and columella. A cartilage graft was used both on the dorsum and in the columella to gain the required result.

tervals. Further, this rib necrocartilage was microscopically compared with autogenous cartilage under similar circumstances (Fig. 11).

After the first week, the cartilage implants showed some local foreign body reaction in the circuitous tissue. The cartilage itself was intact but for slight dissolution of the cells around the periphery. After 6 weeks, the surrounding tissue showed little local reaction, and the cartilage itself presented well preserved cells with distinct nuclei. The matrix stained blue throughout and at the periphery took up a pink stain. After 6 months the microscopic picture varied little from the previous one except that the periphery presented a slight dissolution of nuclei and cells. At the end of 2½ years a previously measured specimen was removed and it was found that the dimensions and gross consistency had not changed

Fig. 15a.

Fig. 15b.

Fig. 15c.

Fig. 16a.

Fig. 16b.

Fig. 16c.

Fig. 15. Primary harelip repair. a, The flattened ala, the deformity of the lip, and vermilion border are of primary concern. b, The lines of incision, the points of approximation and the area to be undermined are depicted. Careful planning of the operation and the future course are prime requisites. c, Following reconstruction. Further surgery on the nose may be postponed until the child approaches adolescence at which time a total rhino-osteoplasty may be done.

Fig. 16. Primary harelip repair. a, Fullness of the lip on the short side. Cognizance of the picture is important, and tissue must be utilized and adjusted to gain desired result. b, The incision on short side is carried lateral to alar attachment. The floor of nose is repaired to compare with opposite side. c, Following surgery.

Fig. 17a.

Fig. 17b.

Fig. 17. a, b, Primary harelip. The lip and nasal deformity have occurred in conjunction with a complete unilateral cleft palate. The anterior floor of the nose is reconstructed by gaining a triangular flap from the short side. Thorough undermining of both cheeks as well as the affected nasal ala past the midline is most important.

Fig. 18a.

Fig. 18b.

Fig. 19a.

Fig. 19b.

Fig. 20.

Fig. 18. a, b, Primary harelip. Though this is an incomplete cleft, it is presented to emphasize that the lines of incision must be carried to the floor of the nose and that the latter along with the nasal ala must be surgically adjusted in order to attain the desired result.

Fig. 19. a, b, Primary harelip repair. The lines of incision and areas to be undermined are illustrated. The flaring short side requires that point *2'* be placed lateral to the left alar attachment in this manner reconstructing the deformity so that it will compare with the opposite side.

Fig. 20. Secondary harelip and cleft palate. This patient, aged 24, had several operations in childhood. In one, the premaxilla and a good portion of the soft palate were removed. Because of the former's absence, the whole palate has contracted, the premolars are anterior, and the upper lip is markedly retruded. In spite of the short, tight palate, the patient presents quite good enunciation because of speech training.

Most of the matrix stained pink and the cells at the periphery were less well preserved than those in the center. The periphery also presented several areas of focal necrosis.

Comparatively, for the first several months the identical cartilage kept in solution was hardly discernible microscopically from that implanted in the body. The section examined after 1 year shows the necrocartilage retained in solution better preserved than that implanted in the anterior abdominal wall. However, the implant of necrocartilage when compared with an implant of autogenous cartilage buried for the same length of time shows little relative difference. Both present some dissolution of the architecture of the cartilage at the periphery and similar change of the cellular and nuclear structure. Grossly, the two pieces hardly differed when compared.

Clinically, as long as 3 years afterward, the intranasal necrocartilage implants appear intact and responsible. In no case did we meet with infection or drainage. All healed primarily and their clinical course from the standpoint of induration, redness, tenderness, etc. was no different than our experience with autogenous cartilage transplants. Our series of necrocartilage transplants that have

been followed both clinically and microscopically number 62.

*Preparation of the necrocartilage implants.* The necrocartilage grafts are prepared several days before surgery. Both the patient and the cast are used as a model, and the specimen is first sculptured grossly with the scalpel. Then the electric burr and fine sandpaper are employed to gain exact size, contour, and smoothness. Several small holes are made in the prepared cartilage to allow granulation tissue to push through to hold it in place.

The cartilage is then cleansed and returned to the refrigerator in merthiolate solution. When the graft is implanted at the operating table, it may be sprinkled with sulfanilamide crystals to aid both in asepsis and fibrosis.

### SURGERY OF THE LIP

The lines of incision are carefully marked with three per cent gentian violet solution. The opposite side is used as a criterion in repairing the affected side. As much as possible of the old scar or notching is removed without creating a lip that is too long or tight. Incisions are carried along the alveolar margins on both sides, and the cheeks are freed from the maxilla (Fig. 3). The former are undermined, allowing the lip to advance toward the center. Incisions are made through the full thickness of lip, the necessary amount of scar is removed, and the floor of the nose and muscles of the lip are approximated with buried fine white silk (Fig. 12).

A subcuticular suture is employed to avoid the ladder scars and a few fine silk sutures are placed in the skin and removed early. The vermilion border is interdigitated in the shape of a "V" forward on one side and reverse on the other. A Bowman's splint is applied and the diet is fluid for several days.

In those patients with a short retruded lip, after having gained tissue from either cheek we may insert cartilage within the lip extending from ala to ala under the nose and down to the vermilion border. Because these patients have previously used the upper lip but little for speech, the cartilage within the lip is not an inconvenience. The lip is thrust outward causing it to stretch so that time improves the result.

*Pedicle flaps from the lower lip.* The vermilion border flap from the lower lip (Eastlander or Abbe flap) with the inferior labial artery intact and attached on one side has often been used (5). Though the transfer may be satisfactory in expert hands, the resultant scar both on the lower and upper lip, and the possible difference in color of the flap with the passage of time has made us feel that its employment is limited. We consider its use in patients with bilateral harelip in whom the prolabium has unfortunately been discarded at some previous operation. Often in such cases the lower lip is markedly prominent and giving up some of its tissue improves the cosmetic appearance (Fig. 13).

*Dermal grafts.* These grafts are easily obtained especially with the use of the Padgett dermatome. The thick split skin graft is cut first, then the required derma is dissected free as one does a full thickness graft. A pocket is created within the upper lip preferably through the old scar, and the dermal graft is inserted. Sulfanilamide crystals are sprinkled over the graft previous to its implantation. The presence of the graft allows for prominence of the lip and is especially applicable for those cases of upper lip retrusion with scarring and fibrosis.

Lyndon Peer (16) followed the fate of full thickness grafts transplanted beneath the thoracic skin of humans. His conclusions indicated that the sebaceous glands do not survive transplant and further that no cyst formation occurred after 28 months. We have since repeated his work and verified his results.

*Vermilion border.* In most cases there is both asymmetry and disappearance of the vermilion border. Women may employ lipstick to create an illusion, men, however, are limited with cosmetic applications. The border may be reconstructed by removing the required amount of skin and vermilion lip, undermining the latter, and suturing it to its new position. Adjusting or sliding the mucous membrane may often be necessary to gain the required result(8).

### TIME TO OPERATE IN SECONDARY PROCEDURES

Secondary procedures on harelip deformities may be performed at any age. As a rule we wait until the patient has passed adolescence before a complete rhinoplastic operation is performed (1). Depending upon the individual patient, the extent of the deformity and the psychic affect it has produced may influence the surgeon to operate at an earlier age. It is our experience that rhinoplasty may be done when the patient is 7 or 8 years of age without deleterious effects. Care must be taken that there is no injury to the vomer during the process of straightening or adjusting the septum.

### PROSTHESIS AND ASSOCIATED CLEFT PALATE DEFORMITIES

Often a patient with an anterior cleft or markedly deformed palate, partially edentulous, re-

quires a prosthesis. Working in conjunction with a trained dentist, the surgeon may construct the prosthesis to give the upper lip some support and protrusion without its being cumbersome and uncomfortable to the patient (10).

All patients who have had a cleft palate repair must be urged to undergo speech training for defective enunciation. Though a good secondary lip repair may be accomplished, a patient with the telltale palate speech will gain less of a psychological improvement than if his speech were helped. Many patients with cleft palate speech are not conscious of the extent of their speech impediment, so that self improvement is virtually impossible and they must seek the services of a teacher.

Patients with a short tight palate and most with the soft palate missing may have good speech and are able to project the hard consonants, whereas other patients with a reasonably good palate are speech cripples (Fig. 20). Too often these patients are reoperated upon, thus producing a better palate but no improvement in speech. In these patients speech training should be tried first and surgery reserved with judgment.

SUMMARY

1. Surgical principles in repair of secondary harelip deformities have been evaluated.

2. The importance of rhino-osteoplasty in secondary repair has been emphasized.

3. Necrocartilage has been followed experimentally and clinically in 62 cases and its use in these deformities judged.

4. The use of dermal grafts has been pointed out.

5. Prosthesis are important adjuncts in harelip repair.

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# AN EVALUATION OF THE CLINICAL SIGNIFICANCE OF SERUM AMYLASE AND LIPASE DETERMINATIONS

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ALTHOUGH a number of studies have been made of the significance of serum amylase and lipase in pancreatic disease, more information is needed in regard to the relative diagnostic value of the two procedures. In 1929, Elman, Arneson, and Graham reviewed the literature dealing with the value of serum amylase determination in pancreatitis, and, more recently, Lewison has presented a review of the subject. The study of serum lipase in connection with pancreatic disease was stimulated in this country by Crandall and Cherry. Comfort and Osterberg (2, 3) have presented unequivocal evidence of its value in pancreatic disease in several papers. Johnson and Bockus (10, 11) have reviewed the status of the determination of this enzyme as an aid in diagnosis.

It is the purpose of this paper to compare and contrast the two procedures in the diagnosis of acute pancreatitis as well as in certain other upper abdominal disorders. One hundred and twenty-two consecutive serum amylase determinations in 104 patients and 165 consecutive serum lipase determinations in 135 patients provide the basis for this study. In 61 cases, both enzyme tests were performed.

## METHODS

Serum lipase was determined by the method of Crandall and Cherry[1]. Serum amylase was determined by the method of Somogyi (15) modified by substitution of the Folin (7) blood sugar method for the Shaffer-Hartman-Somogyi method. The modified method gives somewhat lower results than the original due to the greater specificity of the Folin reagent. Split products of amylolytic digestion affect the reagent employed by Somogyi to a much greater extent than does that of Folin, causing the former to give higher results. Results are expressed as reducing substances (in terms of glucose) liberated per 100 cubic centimeters of serum. Lipase values are expressed as the cubic centimeters of one-twentieth normal sodium hydroxide required to neutralize the fatty acid liberated by 1 cubic centimeter of serum from the olive oil substrate during 24 hour incubation at 38 degrees C.

## NORMAL VALUES

Our experience leads us to believe with Comfort that serum lipase does not normally exceed 1.5 cubic centimeters of twentieth normal sodium hydroxide per cubic centimeter of serum.

In a previous study (14), the normal range of serum amylase when the modified Somogyi method was used was found to be 62 milligrams per 100 cubic centimeters with a standard deviation of 13 milligrams. The normal limits thus were 36 milligrams to 88 milligrams (mean plus or minus twice the standard deviation). Because these figures differed appreciably from those mentioned by Somogyi as normal (80 to 180 mgm. per 100 c.c.), a second series of controls was examined as part of the present study. The results are shown in Figure 1. Here, the mean value is 61 milligrams and the standard deviation 19 milligrams, making the normal range 23 to 99 milligrams. The results obtained by Somogyi differ from the preceding less than these figures would indicate, since he rejected a number of normal values below 80 milligrams without any apparent statistically sound reason. Therefore, combining our two series of controls, we have in this paper considered as abnormal serum amylase values over 100 milligrams and less than 30 milligrams.

## DISEASES OF THE PANCREAS

In Table I, it will be seen that 12 of 13 cases of acute pancreatitis showed serum lipase values over 1.5 cubic centimeters. All of the 9 cases in the amylase series had values over 100 milligrams per 100 cubic centimeters, and 8 of the 9 showed values over 200 milligrams. This is in accord with the results of other authors. Fifty-five per cent of the diagnoses in this group were proved by autopsy or operation. The patient who exhibited a normal lipase value (1.2 cubic centimeters) had an elevated serum amylase of 206 milligrams. This patient did not enter the hospital until several weeks after the onset of symptoms; it is of interest, therefore, that the high serum enzyme activity persisted, since several authors have shown that

With the technical assistance of George R. Kingsley, M.S., and Eleanor Fortunato.

This contribution was prepared from the wards and Division of Biochemistry, The Philadelphia General Hospital.

[1]In determination of serum lipase, buffer solution was omitted since it was found that the absence of the buffer recommended did not influence results appreciably.

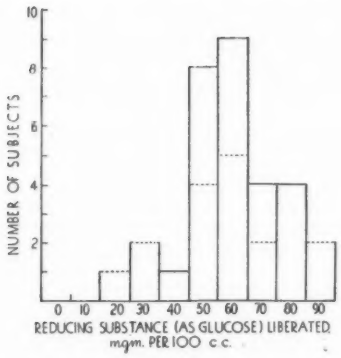


Fig. 1. Serum amylase in normal subjects. Dotted lines, present group; solid lines, combined group—data of Riggs and associates included.

the serum enzyme rise reaches its peak in about 72 hours and thereafter declines quite rapidly.

Serum amylase determinations were done in 7 cases and serum lipase in 16 cases of carcinoma of the head of the pancreas. Four of the amylase group and 12 of the lipase group had the diagnosis proved at either operation or autopsy. Only 1 of the 7 cases in the amylase series showed an elevation, while 9 of the lipase values had titres over 1.5 cubic centimeters. Wakefield, McCaughan, and McVicar found high amylase values in 6 of their 20 cases, but others have found a lower proportion of elevated values. Lewison's recent results are quite comparable with ours in that he found an elevated serum amylase in but 1 of 9 cases. On the other hand, using the lipase test, Comfort and Osterberg (3) in their series of 69 cases of carcinoma of the head of the pancreas found 40.5 per cent elevated. In this same group the amylase was elevated in only 2 of 24 cases. It is seen from these figures that serum lipase is affected more than serum amylase in cases of carcinoma of the head of the pancreas. Greater significance, however, should be attached to the fact that high lipase together with normal amylase, particularly in the presence of painless jaundice, is frequently associated with this condition and strongly suggests such a diagnosis.

In a group of miscellaneous diseases of the pancreas, 1 case of pancreatic calculosis with diabetes mellitus showed an elevated serum lipase of 2.2 cubic centimeters. Three of 5 cases in the amylase series had values over 100 milligrams. These were cases of pancreatic abscess (125 mgm.), pancreatic cyst (280 mgm.), and metastatic carcinoma from the breast (331 mgm.).

The total figures in all diseases of the pancreas as seen in Table I show that 58 per cent of the 38 cases in the lipase group, and 52 per cent of the 21 cases in the amylase group had elevated values.

### DISEASES OF THE LIVER

Of the 10 cases of portal cirrhosis of the liver in the amylase series (Table II), all had values below 100 milligrams. Six of these were under 50 milligrams, and 4 were below 30 milligrams. In a group of cases without demonstrable liver disease (Table IV) only 3 per cent had a serum amylase under 30 milligrams. In the lipase series the same number of cases of portal cirrhosis show a more variable distribution of values although none exceeded a titer of 1.5 cubic centimeters. Thirty per cent of these were 0.3 cubic centimeter or less. However, the fact that the group of cases without any sign of liver disease (Table IV) also showed 30 per cent of the lipase determinations to be 0.3 cubic centimeter or below, indicates that low lipase activity is not necessarily significant in hepatic disease.

Only 3 cases of primary liver neoplasm were encountered; none had elevated values and 1 had a serum amylase below 30 milligrams.

Thirteen cases of acute hepatitis (this classification includes all cases of infectious jaundice and acute toxic jaundice) are included in the lipase series, and 8 cases in the amylase series. Only one had an elevated enzyme value (lipase 1.6 c.c.). This case presented a clinical course typical of "catarrhal" jaundice and recovered completely. Two of the amylase values were below 30 milligrams.

Johnson and Bockus (10) found no lipase titrations over 1.0 cubic centimeter in 15 cases of catarrhal jaundice and 2 cases of toxic infectious hepatitis. Foged found no elevations in 28 cases of acute hepatitis. Therefore our results agree with the findings of these workers.

Eight cases of miscellaneous liver diseases are presented in Table II. These included 2 cases of Hanot's hypertrophic biliary cirrhosis, 4 cases of metastatic malignancy, and 2 of liver abscess. There were no values over 1.0 cubic centimeter for lipase or over 100 milligrams for amylase, while 2 of the 5 amylase figures were under 30 milligrams.

In all types of liver disease, low amylase activity was prevalent, and 26 per cent of the total were under 30 milligrams. Only 1 patient showed an elevated amylase activity.

### GALL-BLADDER DISEASE

Included in our investigation were 16 cases of chronic calculous cholecystitis in the lipase group, 9 with common duct stones, and 17 cases in the amylase group, 6 with common duct stones. There

TABLE I.—SERUM AMYLASE AND LIPASE IN DISEASE OF THE PANCREAS

| Pancreatic disease | Lipase | | | | | | Amylase | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total cases | c.c.N/20 NaOH | | | | | Total cases | Mgm. glucose liberated/100 c.c. | | | | | |
| | | 0.1-0.3 | 0.3-0.5 | 0.5-1.0 | 1.0-1.5 | Over 1.5 | | Below 30 | 30-50 | 51-100 | 101-150 | 151-200 | Over 200 |
| | | Per cent of total | | | | | | Per cent of total | | | | | |
| Pancreatitis, acute | 13 | 0 | 0 | 0 | 8 | 92 | 9 | 0 | 0 | 0 | 11 | 0 | 89 |
| Carcinoma of head of pancreas | 16 | 0 | 19 | 12 | 12 | 57 | 7 | 0 | 43 | 43 | 0 | 0 | 14 |
| Other diseases | 9 | 45 | 0 | 22 | 22 | 11 | 5 | 20 | 0 | 20 | 20 | 0 | 40 |
| Total | 38 | 10 | 8 | 10 | 13 | 58 | 21 | 5 | 14 | 19 | 10 | 0 | 52 |

is a quite uniform distribution in both groups throughout the normal range, and only 3 cases in each series showed a markedly increased activity. Thus, in the lipase series, 3 of the group showed elevation and all of these had common duct stones. In the amylase series, 3 patients had values over 200 milligrams and 5 patients showed enzyme activity between 100 milligrams and 200 milligrams. Three of the 6 cases in this series who had demonstrable common duct calculi had elevated values.

Not only did the 3 patients with elevated lipase values and the 3 with amylase activity exceeding 200 milligrams have calculous common duct obstruction, but 4 also had demonstrable pancreatic involvement. One had a typical acute pancreatitis with widespread fat necrosis and 3 showed some pancreatic induration grossly or definite pathologic changes microscopically. In the other 2, the pancreas was not examined at operation. Likewise, the pancreas was not examined in those patients of the amylase group with values of 100 milligrams, either because of the patient's refusal to undergo operation or because of some technical difficulty during the operation. The 3 patients presenting normal amylase values with stone in the common duct showed no pancreatic involvement. Of the 6 with normal lipase values and calculous common duct obstruction, 5 showed the pancreas to be normal and 1 showed some parenchymatous change of the organ microscopically. In the latter, both enzyme tests were done one day after the onset of symptoms; the lipase titration was 0.6 cubic centimeter of one twentieth normal sodium hydroxide, but the serum amylase was 244 milligrams. Thus, again, as indicated in the pancreatic disease group (Table I), the advantage of performing both of the enzyme tests is unmistakable.

Thirteen cases of acute cholecystitis were studied; none had increased enzyme activity but 2 of the 6 cases of the amylase series had values below 30 milligrams. One of the 5 cases of chronic cholecystitis without stones, in the lipase series, had an elevated value of 2.2 cubic centimeters; the pancreas was not examined at operation, however. Again, a single low amylase value was encountered in this group. There were 9 cases of carcinoma of the gall bladder or extrahepatic bile ducts without increased enzyme activity; however, 3 of the 4 cases in the amylase series had values less than 30 milligrams.

TABLE II.—SERUM AMYLASE AND LIPASE IN DISEASE OF THE LIVER

| Liver disease | Lipase | | | | | | Amylase | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total cases | c.c. N/20 NaOH | | | | | Total cases | Mgm. glucose liberated/100 c.c. | | | | | |
| | | 0.1-0.3 | 0.3-0.5 | 0.5-1.0 | 1.0-1.5 | Over 1.5 | | Below 30 | 30-50 | 51-100 | 101-150 | 151-200 | Over 200 |
| | | Per cent of total | | | | | | Per cent of total | | | | | |
| Cirrhosis | 10 | 30 | 20 | 10 | 40 | 0 | 10 | 40 | 20 | 40 | 0 | 0 | 0 |
| Liver neoplasms | 1 | 0 | 0 | 100 | 0 | 0 | 2 | 50 | 0 | 50 | 0 | 0 | 0 |
| Acute hepatitis | 13 | 8 | 38 | 38 | 8 | 8 | 8 | 25 | 0 | 63 | 0 | 12 | 0 |
| Other diseases | 3 | 67 | 0 | 33 | 0 | 0 | 5 | 40 | 40 | 20 | 0 | 0 | 0 |
| Total | 27 | 22 | 26 | 30 | 18 | 4 | 25 | 36 | 16 | 44 | 0 | 4 | 0 |

TABLE III.—SERUM AMYLASE AND LIPASE IN DISEASE OF THE GALL BLADDER

| Gall-bladder disease | Lipase | | | | | | Amylase | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total cases | c.c. N/20 NaOH | | | | | Total cases | Mgm. glucose liberated/100 c.c. | | | | | |
| | | 0.1–0.3 | 0.3–0.5 | 0.5–1.0 | 1.0–1.5 | Over 1.5 | | Below 30 | 30–50 | 51–100 | 101–150 | 151–200 | Over 200 |
| | | Per cent of total | | | | | | Per cent of total | | | | | |
| Acute cholecystitis | 7 | 29 | 29 | 13 | 29 | 0 | 6 | 33 | 50 | 17 | 0 | 0 | 0 |
| Chronic cholecystitis | 5 | 20 | 20 | 40 | 0 | 20 | 2 | 50 | 0 | 50 | 0 | 0 | 0 |
| Chronic calculous cholecystitis, with and without stone in common duct | 16 | 25 | 19 | 25 | 12 | 19 | 17 | 6 | 35 | 12 | 24 | 6 | 18 |
| Neoplasms—gall bladder and bile ducts | 5 | 0 | 40 | 20 | 40 | 0 | 4 | 75 | 0 | 25 | 0 | 0 | 0 |
| Total | 33 | 24 | 24 | 21 | 19 | 12 | 29 | 25 | 35 | 17 | 10 | 3 | 10 |

The combined figures for all diseases of the gall bladder as seen in Table III, showed elevated activity in 4 of the 32 cases in the lipase series. Eight of the 29 cases of the amylase series had values less than 30 milligrams and the 7 with amylase values over 100 milligrams occurred in cases of chronic calculous cholecystitis.

### OTHER DISEASES

Serum enzyme tests were done on 66 cases with diseases other than those already discussed. Elevated values were observed in 4 of the 37 cases in the lipase group, and in 7 of the 29 cases in the amylase group. The latter ranged between 100 and 200 milligrams. None of these cases came to operation or autopsy. However, all but 2 had severe symptoms referable to the upper abdomen and 5 were shown by x-ray to have intra-abdominal neoplastic disease. We can only surmise that there was some pancreatic involvement in these cases, but, because of lack of proof, no definite opinion as to the cause of these elevated enzyme values can be made. Heifitz, Probstein, and Gray have shown that renal insufficiency causes an increase in serum amylase and this factor probably explains some of the moderately elevated values. Only 1 patient presented an amylase value below 30 milligrams.

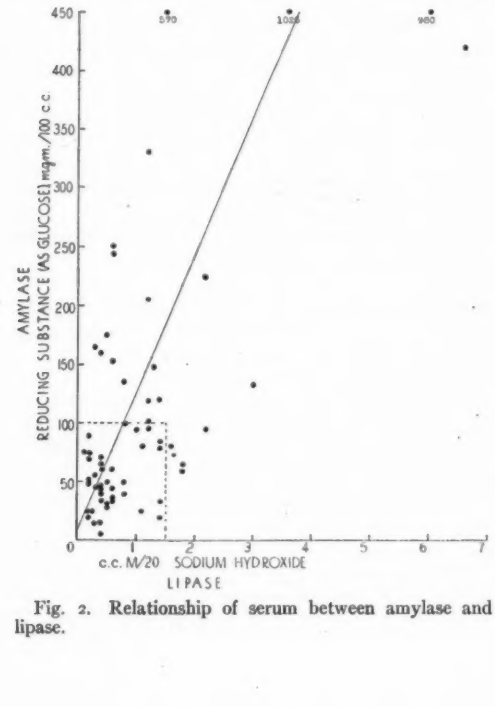


Fig. 2. Relationship of serum between amylase and lipase.

### CORRELATION AND APPLICABILITY OF THE TWO ENZYME TESTS

Correlation between serum amylase and lipase activity was not as close as had been anticipated (Fig. 2). The coefficient of correlation for the entire group was 0.66. Although this figure is statistically significant, it may be concluded that of the factors governing the activity of these enzymes, only two-thirds are common to both, and that an appreciable degree of independence exists. Calculation of regression of amylase on lipase failed to yield a significant regression coefficient, which is a further indication of an independent behavior of these enzymes.

Lipase was normal in the presence of elevated amylase more frequently (12 of 18 times) than amylase was normal in the presence of elevated lipase (4 of 10 times). However, when tested by the Chi square method, this difference was found to be nonsignificant.

Technically, both serum amylase and lipase determinations can easily be performed by the ordinary hospital laboratory. However, because

TABLE IV.—SERUM AMYLASE AND LIPASE IN OTHER DISEASE

| Lipase | | | | | | Amylase | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | c.c. N/20 NaOH | | | | | | Mgm. glucose liberated/100 c.c. | | | | | |
| Total cases | 0.1–0.3 | 0.3–0.5 | 0.5–1.0 | 1.0–1.5 | Over 1.5 | Total cases | Under 30 | 30–50 | 51–100 | 101–150 | 151–200 | Over 200 |
| | Per cent of total | | | | | | Per cent of total | | | | | |
| 37 | 30 | 16 | 27 | 16 | 11 | 29 | 3 | 21 | 51 | 14 | 11 | 0 |

of the greater rapidity with which amylase can be measured (less than 1 hour), and the ease with which the ordinary blood sugar methods can be adapted to this test, amylase determinations are clinically more useful. This is especially true in cases of acute upper abdominal disease. The lipase determination, as has been pointed out, is helpful as an aid in the diagnosis of carcinoma of the head of the pancreas. In such cases speed is not necessary. Our experience also suggests the desirability of doing both tests in obscure cases.

## EVALUATION OF STUDY

Evidence presented in this paper and in many others shows that the blood serum amylase and lipase are valuable aids in the diagnosis of acute pancreatitis provided the determinations are done soon after the onset of symptoms. It is also evident that alterations in the activity of these serum enzymes may be used to advantage in diagnosing carcinoma of the head of the pancreas. In this disease, the presence of painless jaundice, normal serum amylase, and elevated serum lipase is a combination of diagnostic import.

Somogyi (16) states that low serum amylase is "found only in cases in which some form or other of liver damage and subsequent impairment of liver function is present," and Gray, Probstein, and Heifitz are in agreement with this view. In our study, the group of cases with liver disease had more low serum amylase values and fewer high enzyme values than did any other group. However, the low values did not occur with a sufficient degree of consistency to warrant the use of serum amylase determinations as a liver function test. Low amylase activity was somewhat more prevalent in cases of chronic jaundice (Table II) than in cases of acute jaundice.

In 1933, Foged pointed out that urine amylase was often elevated in cases of cholelithiasis with common duct stone, and in 1938, Branch and Zollinger in this country found high blood serum amylase in 3 of 6 cases. Millbourne has presented a group of 74 cases with obstructive jaundice due to stone in the common duct of which 53 per cent had high values. It is interesting to note that 11 of these patients were proved to have had an accompanying acute pancreatitis. In our study, all of the cases with common duct stone that had high values, in which the pancreas was examined, showed pathological changes in that organ, and all those with normal values had normal pancreases. Although pancreatic exploration was not carried out in all of our cases, it would seem likely from these observations that elevated serum enzyme values in cases of calculous common duct obstruction were due to underlying pancreatic pathology. Therefore, increased enzyme activity is not a test for stone in the common duct *per se*.

## SUMMARY

1. The relative diagnostic value of serum amylase and serum lipase in patients with diseases of the pancreas, liver and gall bladder has been compared.

2. The normal values of serum amylase depend upon the blood sugar method employed in the measurement of reducing substances liberated by amylase action. When the Folin copper reduction method is used in the Somogyi technique, normal serum amylase averages 62 milligrams and ranges from 30 to 100 milligrams.

3. Both amylase and lipase determinations are of great value as aids in diagnosing acute pancreatitis.

4. In carcinoma of the head of the pancreas, the serum lipase is usually increased and the serum amylase normal.

5. In liver disease the serum amylase activity is likely to be depressed but not with sufficient consistency to enable the use of this change in diagnosis.

6. The serum enzyme activity in cases of calculous common duct obstruction appears to be increased only in those cases in which the pancreas has been damaged.

7. The coefficient of correlation between serum amylase and lipase activity was 0.66. The value of amylase and lipase determinations thus is increased when both enzymes are determined.

8. Both enzyme tests can easily be done by the ordinary hospital laboratory. The serum amylase test is usually the most useful clinically because of the rapidity with which it can be performed.

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# EDITORIALS

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APRIL, 1945

## THE MISSION OF SURGICAL SPECIALISTS IN THE U. S. ARMY

IN February, 1942, the Surgeon General established in his office Professional Consultant Divisions in Surgery, Medicine, and Neuropsychiatry, thereby giving official cognizance to the importance of these specialized clinical functions and setting the standard of organization of professional services in other echelons of the Medical Department of the Army. Subsequently, and as rapidly as the needs dictated, each of these professional consultant divisions expanded its staff and organization to include functional representation in their respective fields of specialized endeavor. Thus, in the surgical consultants division there have been created branches in general surgery, orthopedic surgery, neurosurgery, ophthalmology, otolaryngology, radiation, transfusion therapy, and chemical warfare. The functions of these professional consultant divisions may be broadly described as administrative, correlative, advisory, educational, and analytical.

In addition to the Chief Surgical Consultant and his staff in the Office of The Surgeon General, Surgical Consultants have been assigned to every Service Command in the Zone of Interior, to all active Theaters of Operation, and to every active army. Selected on the basis of their special training and background and their eminent qualifications in their respective fields of endeavor, these consultants are concerned essentially with the maintenance of the highest standards of medical practice. It is their function to evaluate, promote, and improve further the quality of medical care by every possible means, to interpret the professional policies of the Surgeon General and to aid in their implementation. The proper performance of these functions necessarily involves an appraisal of all factors concerned with the professional services in medical installations, the quality, numbers, distribution and assignment of professional personnel, the diagnostic facilities, the availability and suitability of equipment and supplies for professional needs, and other auxiliary services which are essential to the welfare and morale of patients. The surgical consultants exercise their functions by assisting and advising the Service Command and Theater Surgeons on all matters pertaining to surgical practice, including particularly the organization and program of surgical services in medical installations and the quality, distribution, and proper assignments of professional personnel, by providing advice on newer developments in diagnosis and treatment, by stimulating interest in professional problems and aiding in their investigation, and by encouraging educational programs such as conferences, ward rounds, and journal clubs. The

excellent manner in which they have executed their functions, the industry and zeal they have manifested, and the high standards of medical practice in the Army they have helped to elevate are most gratifying. That this entire program was inaugurated with wisdom and foresight is demonstrated by the fact that from surgical consultants in overseas theaters, as well as service commands, have been received valuable reports which have made possible appropriate modifications of existing medicomilitary practice and the institution of more efficacious procedures and innovations.

In the overseas theaters of operation the surgical consultants have shouldered their great responsibilities in a most commendable manner. By assiduous and unrelenting attention to the multitudinous personnel and professional problems which have arisen, they have been responsible in no small measure for the effective surgical treatment which has saved more lives in this war than in any previous conflict in the history of the world. Constant vigilance for methods of implementing earlier and better surgery with a determined effort toward reducing even further an already unprecedentedly low mortality among the wounded, has characterized their activities from the date of their assignment.

Civilian surgical consultants in the United States have likewise been appointed on the recommendations of the Surgical Consultants Division of the Office of the Surgeon General. In the specialized surgical fields, civilian consultants have been appointed in ophthalmology, otolaryngology, neurosurgery, orthopedic surgery, surgery of the hand, thoracic surgery, and anesthesia. These civilian consultants, who have given of their time so unstintingly whenever called upon, have periodically visited hospital installations in the Service Commands and have furnished to the Surgeon General reports which include constructive criticism with suggestions for further elevating the caliber of surgical care being rendered in the Army. The favorable comments which these civilian consultants, chosen for their eminence in their particular specialties, have made in regard to the high level of surgical practice observed have been a source of pride to the Surgeon General.

The creation of specialized surgical centers in the general hospitals in the Zone of Interior represents another progressive innovation in the Medical Department's program of furthering professional service and clearly reflects the Surgeon General's policy to foster specialized surgical care by highly trained specialists. At the present time in the field of surgery there have been established 48 units in general hospitals in the Zone of the Interior designated for the specialized care of the various types of injuries and surgical diseases. These include 6 centers for amputations, 21 for neurosurgery, 5 for thoracic surgery, 3 for vascular surgery, 8 for plastic surgery, 8 for ophthalmologic surgery, and 2 for the rehabilitation of the blind and 3 for the deaf. The centers have been staffed by well trained and highly qualified specialists in these various surgical fields of endeavor and no effort has been spared in providing them with the most modern technical equipment and specialized facilities required for this type of work. It should be said that these installations afford an ample opportunity for on the job training to young surgeons whose apprenticeship was interrupted by the war. Obviously, nothing approximating the complete training in residency afforded by civilian teaching hospitals in peace time can be accomplished, for many reasons. However, it is not too much to say that this training in these designated hospitals under civilian surgical specialists, teachers in uniform, compares favorably in caliber with its counterpart in civil practice and, in

all likelihood, all of the specialty boards will grant for it certain credit in their requirements for certification. Indeed, the American Board of Surgery has already agreed to give 1 year's credit for training in army hospitals.

Recognizing the importance of specialized training and the significance of its efficient utilization, the Surgical Consultants Division in the Office of the Surgeon General has since its inception been intensely interested in the proper assignment of surgical personnel and has continued to devote considerable effort in this direction. It has been considered essential to assure the assignment of suitably qualified personnel to key surgical positions in army hospitals. From time to time there has appeared some criticism of malassignments, inconsonant rank, and other evidence of "round pegs in square holes." In an organization which has mushroomed in growth from less than 1,300 members to nearly 35 times this number, it is only reasonable to expect such administrative errors, particularly during the rapid expansion. However, the correction of these unfortunate but sincere mistakes has been vigorously pursued and a determined effort has been made to reduce them to a minimum. That this effort has been attended by some measure of success is demonstrated by the results of a recent survey of surgical personnel in the Army.

The accompanying table is an analysis of assignments of surgeons who are certified by specialty boards or have equivalent qualifications and are now serving in army installations in the Zone of the Interior.

This sample of 922 qualified and certificated surgical specialists shows that 96 per cent of the surgeons in these categories recognized by the Army are doing surgery in their own specialty in army hospitals. The 37 surgeons in the same category who are not doing surgery are serving as consulting surgeons either in the Office of the Surgeon General or in the nine Service Commands into which the Continental United States is divided. That a parallel disposition of talent be carried out in the theaters of operation has been a goal toward which the Army has pointed. The very fact that so many hospital units were sponsored by medical schools, clinics, and teaching hospitals enabled the Army at the beginning of the war to concentrate a large pool of surgical talent which, being accepted for overseas service, guaranteed a distribution of surgical specialists in the theaters of operation. These specialists, distributed throughout the theater to other installations less fortunately manned, elevated the general level of surgical service insuring to the wounded man skilled care.

| | Nonsurgical duties | | Surgical duties | | Total |
|---|---|---|---|---|---|
| | No. | Per cent | No. | Per cent | No. |
| General surgery | 23 | 9.9 | 209 | 90.1 | 232 |
| Neurosurgery | 0 | 0 | 27 | 100 | 27 |
| Orthopedic surgery | 7 | 4.6 | 143 | 95.4 | 150 |
| Urological surgery | 0 | 0 | 86 | 100 | 86 |
| Plastic surgery | 0 | 0 | 14 | 100 | 14 |
| Thoracic surgery | 0 | 0 | 8 | 100 | 8 |
| Ophthalmology | 3 | 1.8 | 167 | 98.2 | 170 |
| Otolaryngology | 4 | 2.0 | 196 | 98 | 200 |
| E.E.N.T. | 0 | 0 | 35 | 100 | 35 |
| Total | 37 | 4 | 885 | 96 | 922 |

The program of supervision, co-ordination, and policy-making originated in the Surgeon General's Office and, integrated throughout the various echelons in the Zone of the Interior and the theaters of operations, has resulted in an equable distribution of surgical talent and a consequent maintenance of a high standard of surgery always comparable, frequently superior, to that available to a cross section of the population of the country.

Indeed, the ambition of the Surgical Consultants to the Surgeon General of the U. S.

Army has been to establish definitive treatment of wounded soldiers in a parallel direction to the trend in specialization which has been fostered in this country during the last two decades. Medical schools have emphasized the importance of formalizing programs of apprenticeship in the various special fields of surgical endeavor and the Army, by reason of having the vast majority of the young, vigorous, well trained surgical specialists in its ranks, has profited thereby. As a result of this educational development, more capable young surgeons were available to the Army at beginning of this war than was the case in any army hitherto mobilized anywhere in any war. It but remained for the Surgeon General's Office to implement their assignment in appropriate installations to the end that their talents might be used to the fullest. The test of this endeavor is reflected in present day mortality and morbidity statistics.

That the Army of the future may profit by this experience to the end that it develops specialization within its own ranks and encourages formalized training by its own officers for its own officers in large army hospital-clinic-centers geographically distributed through the country, is a dream not impossible of realization. There are in the Army at this time a sufficient number of civilian surgeons who could and would willingly forward such a program were they encouraged in the belief that their suggestions and examples would be welcome and appreciated. Planning to this end is imperative. The responsibilities of the surgical profession in an expanding internationalism challenge the imagination.

*"Where there is no vision, the people perish."*

*Proverbs XXIX, 18.*

FRED W. RANKIN
Brigadier General, U. S. Army
Chief Consultant in Surgery

## PERIPHERAL NERVE SURGERY

IT is agreed by neurological surgeons and neurologists that the principles which underlie the surgical treatment of peripheral nerve injuries are not well understood by the civilian and military surgeons who are in positions to give these patients the most advantageous early and primary care.

The ideal surgical method of repairing a peripheral nerve injury is an accurate end-to-end apposition of the divided ends at the earliest possible moment following division with the finest possible suture material which passes through the epineurium of the nerve trunk.

Peripheral nerves undergo degeneration through their entire course distal to the site of injury. Degeneration extends to the nerve endings on the muscle fibers. The denervated muscles atrophy, fibrosis occurs in unused joints, tendons lengthen or shorten; in brief, the entire effector mechanism which makes an extremity useful is affected. Muscle atrophy and contractures cannot be prevented by physical therapy methods alone; regeneration of the nerve endings in the muscle must occur before muscle fibers have been completely destroyed. It is of little use to obtain an excellent anatomical union of a fractured bone if the paralyzed and atrophied muscles prevent the movement of the extremity.

An end-to-end apposition of a divided nerve end should never be deliberately postponed. The circumstances surrounding the peripheral nerve injuries of warfare may often necessitate a delay in repair, but the fear of an infection in the wound should not be used as a reason to delay the apposition of nerve ends. It has been shown that nerve regeneration may take place in an infected wound, and only when the nerve fascicles within the nerve trunk are involved does infection interfere with the

downgrowth of nerve fibers. Even under the most adverse circumstances the apposition of divided nerve ends will prevent their retraction and the growth of large neuromas which later will necessitate the bridging of a large continuity defect.

It has also been shown that, if in the opinion of the surgeon, the sulfonamide drugs should be used locally or systemically in an effort to control suppuration in the wound, they will not interfere with the regeneration of nerve fibers. There is clinical experience in war injuries to show that infected wounds which have healed may be opened, the nerve sutured, and closed after the introduction of the sulfonamides with little or no danger of activating latent bacteria. This experience contraindicates the long intervals that have been respected in the past before it was deemed safe to reopen the wound and suture a divided nerve. All of these factors must be weighed carefully to insure the earliest possible apposition of a divided peripheral nerve.

If there has been a destruction of nerve tissue which makes end-to-end apposition difficult, every surgical procedure, such as transposition of the nerve trunk from its normal anatomical bed to a shorter course and the flexion or extension of adjacent joints, should be employed to obtain an end-to-end approximation.

If the defect in substance is too great to be bridged by these methods then there is enough experimental and encouraging clinical evidence to justify the use of fresh autogenous or homogenous nerve grafts of approximately the same size as the divided nerve. Occasionally it is justifiable to sacrifice one nerve in an extremity to provide a graft for another, provided both are severely injured. Such an autogenous graft may provide useful function to an otherwise useless extremity. More often, however, homogenous grafts must be employed as a more practical method of bridging a large defect.

Grafts act as a pathway for the regenerating nerve fibers from the central segment of the divided nerve. Although the ectodermal tissue, such as nerve fibers, myelin sheaths, and Schwann (neurilemma) cells, undergoes necrosis most of the mesodermal tissue remains alive. This is most marked in the periphery of the graft where the blood supply is restored soon after transplantation. Capillaries grow from the periphery into the center of the graft and the phagocytes ingest the necrotic material. Soon the endoneural and perineural mesodermal elements proliferate throughout the graft and join with the proliferated mesodermal elements of the central and distal nerve segments at the suture line. The regenerating nerve fibers follow the path of the mesodermal fibers through the suture lines and the graft. Therefore, the proliferation of the mesodermal cells and the formation of mesodermal collagenous fibers are of the utmost importance for the regeneration of a nerve through a graft. Until recently most investigators have underestimated the importance of this mesodermal proliferation in the process of nerve regeneration, because they failed to visualize the mesodermal tissue in their nerve fiber stains and to see its relation to the regenerating Schwann cells and nerve fibers.

The survival of the mesodermal elements is important in the transplanted grafts and therefore it is necessary for the graft to be fresh if it is to be successful. Stored grafts which have been fixed in formalin and dehydrated in alcohol are bound to be unsuccessful because they are dead and remain dead. When transplanted these fixed grafts undergo complete necrosis, and it requires a long time for capillaries to proliferate from the surrounding tissues, penetrate the graft, and for the necrotic material to be removed. Delaying the

blood supply, even to a fresh graft, by surrounding the suture lines or the entire graft with metallic sheaths or tubes of any kind will only enhance the necrosis and keep the mesodermal tissue from proliferating. The small adhesions which form about the suture lines and the transplanted graft carry blood vessels which supply the graft. Necrosis of the graft results in a complete disturbance of its structure and is the most serious factor which will prevent the return of a large number of regenerating nerve fibers to their appropriate end organs.

Evaluation of the results of peripheral nerve end-to-end sutures and the use of nerve grafts during World War I has been unsuccessful for many reasons, the most important of which has been the lack of uniformity in the examination of recovery of motor and sensory function and in the criteria to establish such recovery and, second, the lack of follow-up records of the patients. At present there is a tendency to evaluate the results of grafts after periods of time far too short following operation. Six months or more frequently elapses following an end-to-end suture under ideal conditions before the first evidence of recovery occurs, and to expect evidence of recovery after the same period of time following the use of a homogenous graft is expecting the impossible.

The Surgeon General has already taken steps to insure the examination of patients with peripheral nerve injuries postoperatively while they remain within the Army. It is to be hoped that the Veterans Administration will make a contribution to the progress of surgery by making it incumbent upon the discharged veteran to have a periodical examination by competent neurologists and neurological surgeons until the full data upon the progress of his recovery have been obtained. This dependency of compensation upon periodical examinations is one of the outstanding and most important features of the British plan for the care of disabled soldiers who have suffered peripheral nerve injuries.

LOYAL DAVIS

# THE SURGEON'S LIBRARY

## REVIEWS OF NEW BOOKS

PREPARED by Simmons and his assistants in the Medical Intelligence Division of the Preventive Medicine Service in the Office of the Surgeon General of the United States Army, *Global Epidemiology*[1] "represents an excursion into the unexplored field of geo-medicine, bringing together in one place certain data on medical, health and sanitary conditions of various geographic areas of the world. — This first volume includes medical information about India, the Far East and the Pacific area." The index presents 34 main divisions, but information from 190 separate areas is included. It is a compilation of facts of medical interest contributed from many sources, the first objective of which was to provide material for the intelligent planning for medical care of troops. What remains after the deletion of material of military value is presented in this first volume.

This considerable collection of medical information from 34 countries and island groups has been presented as follows: (1) geography and climate; (2) public health; (3) medical facilities; (4) diseases; (5) summary. Each of the above divisions contains what is known of medical interest in each locality. Sketch maps of the localities under consideration and an appendix containing maps prepared by the Preventive Medicine Division showing the distribution of 14 important diseases throughout the world illustrate the epidemiological features. A striking fact, repeatedly brought out in this book, is that through all possible variations of geography and climate and among several ethnological groups in the areas discussed the public health services and the medical facilities fall far short of the need, in that most of the diseases prevalent in those areas are those which could effectively be dealt with by adequate administration and facilities. The incidence of illness and death due to "dangerous" animals in the tropics is very low comparatively.

This first volume is a valuable contribution to the understanding of the medical problems of the areas under consideration. The information offered is dependable and will be extremely useful to persons responsible for health and hygiene in these areas.

HENRY R. JACOBS.

[1] GLOBAL EPIDEMIOLOGY; A GEOGRAPHY OF DISEASE AND SANITATION. By James S. Simmons, B.S., M.D., Ph.D., Dr.P.H., Sc.D.(Hon.), Tom F. Whayne, A.B., M.D., Gaylord West Anderson, A.B., M.D., Dr.P.H., Harold M. Horack, B.S., M.D., and collaborators. Vol. 1. Philadelphia, London, Montreal: J. B. Lippincott Co., 1944.

## BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

TRANSACTIONS OF THE SIXTY-FIFTH MEETING OF THE AMERICAN SURGICAL ASSOCIATION HELD AT THE THORNE HALL, NORTHWESTERN UNIVERSITY, CHICAGO, ILL., MAY 3-4, 1944. Edited by Walter Estell Lee, M.D. Vol. 62. Philadelphia: J. B. Lippincott Co., 1944.

SURGERY OF MODERN WARFARE. Edited by Hamilton Bailey, F.R.C.S., and C. Allan Birch, M.D., M.R.C.P., D.C.H., D.P.H., M.M.S.A. Vols. 1 and 2. 3d ed. Baltimore: The Williams & Wilkins Co., 1944.

ARTERIAL INJURIES; EARLY DIAGNOSIS AND TREATMENT. By the Vascular Injuries Sub-Committee of the M.R.C. War Wounds Committee. Medical Research Council War Memo. No. 13. London: H. M. Stationery Office, 1944.

SHOULDER LESIONS. By H. F. Moseley, M.A., D.M., M.Ch.(Oxon.), F.R.C.S. (Eng. and C.), F.A.C.S. Springfield, Ill.: Charles C. Thomas, 1945.

THE 1944 YEAR BOOK OF INDUSTRIAL AND ORTHOPEDIC SURGERY. Edited by Charles F. Painter, M.D. Chicago: The Year Book Publishers, Inc., 1945.

SPINA BIFIDA AND CRANIUM BIFIDUM. Papers reprinted from the *New England Journal of Medicine* with the addition of a comprehensive bibliography. By Franc D. Ingraham, M.D., et al. The Children's Hospital, Boston. Cambridge, Mass.: Harvard University Press, 1943, 1944.

MODERN METHODS OF AMPUTATION. By Edmundo Vasconcelos. With an Introductory Survey of The Development of Amputation by Major Gen. Norman T. Kirk, M.C. New York: The Philosophical Library, 1945.

A TEXTBOOK ON PATHOLOGY OF LABOR, THE PUERPERIUM AND THE NEWBORN. By Charles O. McCormick, A.B., M.D., F.A.C.S. St. Louis: The C. V. Mosby Co., 1944.

THE ABORTION PROBLEM. Proceedings of the Conference Held under the Auspices of the National Committee on Maternal Health, Inc., at the New York Academy of Medicine, June 19th and 20th, 1942. Howard C. Taylor, Jr., M.D., Conference Chairman. Baltimore: The Williams & Wilkins Co., 1944.

PYE'S SURGICAL HANDICRAFT; A MANUAL OF SURGICAL MANIPULATIONS, MINOR SURGERY, AND OTHER MATTERS CONNECTED WITH THE WORK OF SURGICAL DRESSERS, HOUSE SURGEONS, AND PRACTITIONERS. Edited by Hamilton Bailey, F.R.C.S. Eng. 14th ed. Baltimore: The Williams & Wilkins Co., 1944.

# CORRESPONDENCE

## MEDICAL CORPS, UNITED STATES ARMY

*To the Editor:* Ever since reading Dr. Lawrence Kubie's editorial in the January issue of SURGERY, GYNECOLOGY AND OBSTETRICS, I have intended to write you.

Dr. Kubie is a man of keen intellect, and I know that his interest in the matter of specialization in the armed services is a sincere one. He wants to help and we want him to help. His criticisms are, in some instances, just, but in others, I think, they are unjust.

We have always had a number of men in the various specialties who were good professionally, but who never tried to qualify before the various Boards. No doubt they should be given more encouragement. Again, we have always had many stations where we had to keep good all-round qualified men, as they were more or less on their own. These men never had a chance to qualify in any specialty. The Army does not try to make every man a general practitioner, however. We know that in time of peace we are preparing for war, and every Regular Army officer must, in time of war, drop his professional work and take up the burden of military medical administration in some form.

There is always a small group of medical officers who are specialists in medical field work. These men are the ones we have to depend on in time of war to go out in key positions with the field forces. They go through our various service schools and are trained for this particular type of duty.

I do not agree with Dr. Kubie in his statement that there was a two year period of fumbling and uncertainty at the beginning of this war. We had a very small reserve of trained specialists and I think the records show they were used to the greatest advantage. At first, there were many jobs to which specialists were assigned because there were not hands enough to do the work. In so far as the records of specialists are concerned, this office has never been reorganized, but still follows the plan put into effect at the beginning of the war.

I agree with Dr. Kubie that, following this war, there should be much closer liaison between the Medical Corps and the various specialty boards and the special societies.

I do not agree with Dr. Kubie that the services attract only the mediocre young physicians. I do not have the time nor the clerical help to make an exhaustive study of this, but I have selected one class at random and examined the records of all members. Most of these records contain signed statements from the deans of medical schools. The results in this class of 36 men were as follows: upper third, 13; middle third, 14; lower third, 3; no report, 4; very satisfactory, 1; good, 1—a total of 36. One man classed in the middle third was not so rated by his dean, who simply gave him a general average of 85 per cent for the four years. Looking over the names in this class, I note that many of the men in the middle third have superior war records.

This has been a much longer letter than I intended to write, but I have stated my case and hope that you will bear with me.

With warmest personal regards, I am

Sincerely yours,

GEORGE F. LULL,
Major General, USA,
Deputy Surgeon General

February, 1945